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THE UNIVERSITY OF ALBERTA

# THE CARDIORESPIRATORY EFFECTS
# OF ICE HOCKEY
# UPON TREADMILL PERFORMANCE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

FACULTY OF PHYSICAL EDUCATION
BY
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EDMONTON, Alberta

September, 1964

# APPROVAL SHEET

## UNIVERSITY OF ALBERTA

## FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies, a thesis entitled "The Cardiorespiratory Effects of Ice Hockey Upon Treadmill Performance" submitted by Ronald Carl Watson in partial fulfilment of the requirements for the degree of Master of Science.

# ABSTRACT.

The purpose of this study was to assess the effects of a season of ice hockey upon treadmill performance as measured by a modified Mitchell, Sproule, Chapman maximal oxygen consumption test. Adjuncts to the main problem were the investigation of maximal heart rates associated with the maximal oxygen consumption, submaximal oxygen consumption, submaximal heart rates, and alterations in total body weight.

Ten University of Alberta varsity hockey players, ranging in age from 20 - 25 years, and 10 University of Alberta undergraduate and graduate students, ranging in age from 19 -28 years, were tested three times over a 21 week period. The testing intervals corresponded to pre, mid, and end of the hockey season.

Within the limitations imposed by the statistical techniques employed and the population studied the following conclusions were made. The season of ice hockey significantly increased the maximal oxygen consumption of the hockey group over that of the control group when expressing it in terms of liters/minute. There was no significant difference in the maximal oxygen consumption of the hockey group compared to that of the control group when expressing it in terms of ml/kg/minute. The maximal heart rates of both the experimental and the control group decreased significantly over the 21 week period but the difference between the two groups was not significant. The hockey group exhibited no

significant superiority over the control group in submaximal oxygen consumption at the zero per cent elevation. The oxygen consumption for the hockey group at the 2.5 per cent elevation was significantly higher than that of the control group in terms of liters/minute but not in terms of ml/kg/minute. There were highly significant differences between the trials. The hockey group exhibited a significant increase in oxygen consumption between the trials for the 5.0 per cent elevation. The difference that existed between the submaximal heart rates of the hockey group and the control group could not be attributed to the ice hockey training program. It is important that body weight be taken into consideration when investigating maximal oxygen consumption. Intermittent activity can increase maximal oxygen consumption and decrease maximal heart rate associated with maximal oxygen consumption. There was no significant change in the mean body weight of the two groups over the 21 week period.

# ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation and gratitude to his committee members, Dr. R.B.J. Macnab, Dr. M.L. Howell, and Dr. B.J. Sproule for their relentless assistance and unperturbed patience throughout this thesis.

To my co-workers, Rod Hyde, Robert Norman, and Peter Stothart, the graduate students who willingly and faithfully contributed so many hours of their already overburdened schedule, an eternal thank you.

Not to be forgotten are the most co-operative group of subjects ever assembled in our laboratory.

A very special appreciation must go to my wife, Shirley, for her timely understanding and her many lonely hours.

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# CHAPTER I

# STATEMENT OF THE PROBLEM

## Introduction

Numerous studies (35, 52, 17, 63, 23, 41) have been conducted concerning the effects of various conditioning methods upon certain physiological parameters but information is not available pertaining to participation in a vigorous ice hockey training program. Undoubtedly changes must occur but knowledge of the direction and magnitude is at present a matter of surmise.

Brouha states (16:403) that:

> Many physiological responses are altered by training. In general the improvement in each bodily system is in the order of 25% or less, but when taken together all the effects may result in an improvement of total performance which may be as high as 100% and occurs in both the magnitude and duration of the work that can be done.

Brouha also developed a list of the known changes of the organism brought about by training, two of which are listed below:

1) Increased maximal oxygen consumption.
2) Improvement in mechanical efficiency (lower oxygen consumption for a given work load).

It may be reasonable to assume that such changes do occur in the cardiorespiratory systems of ice hockey players but scientific evidence is more valuable than empirical extrapolation. The present study was initiated in an attempt to determine, with respect to maximal oxygen consumption and exercise heart rates, whether changes that occur in other

methods of athletic conditioning are applicable to ice hockey.

## The Problem

It was the purpose of this study to investigate the changes in maximal oxygen intake, as measured by a modified Mitchell, Sproule, Chapman maximal oxygen intake treadmill test, that occur in varsity hockey players over a season of ice hockey.

## Subsidiary Problems

The subsidiary problems under investigation were to study the effect of a season of ice hockey conditioning upon the following variables:

1) Maximal heart rate associated with the maximal oxygen intake.
2) Oxygen consumption for given work loads.
3) Heart rate associated with the given work loads.
4) Changes in body weight.

## Importance of the Study

Scientific studies on the cardiorespiratory effects of ice hockey are lacking. Thousands of participants are actively engaged in ice hockey every winter but there has been no attempt to study the nature of the changes that occur in the cardiorespiratory fitness of these individuals. Studies involving well-trained athletes provide a source from which facts can be drawn concerning the direction and magnitude of various physiological changes. The accumulation of such a body of knowledge can provide the tools for

ascertaining the changes that occur in less fit individuals and perhaps assessing optimal, functional levels.

It is generally accepted that the highly conditioned athlete has a higher work capacity than the unconditioned individual, however, it has not been clearly established if the conditioned person is superior to the unconditioned person at submaximal work levels. Data has been presented in an attempt to dissolve some of the uncertainty concerning this matter.

## Limitations

1. The investigation was restricted to ten University of Alberta varsity hockey players and ten, intermittently active University of Alberta undergraduate and graduate students.
2. The cardiorespiratory aspect of conditioning was the only physiological variable investigated, specifically oxygen consumption and heart rate.
3. The length of the ice hockey season was 21 weeks.
4. The control group was composed of intermittently active subjects.
5. The groups were tested only three times, pre-season, seven weeks after the first test, and at the end of the season.
6. A modified form of the Mitchell, Sproule, Chapman maximal oxygen intake test was used.
7. Time limitations prevented the determination of reliability coefficients.

8. Temperature, barometric pressure, and humidity were not controlled.
9. No control was placed upon the subject's activity on the day of the test nor were daily times of succeeding visits to the laboratory extensively controlled.

## Assumptions

a) It has been assumed that the modified Mitchell, Sproule, Chapman maximal oxygen intake test does in fact measure maximal oxygen consumption, keeping in mind that this parameter is specific to the task being executed. The general opinion (4, 24, 9, 58, 1, 63) is that maximal oxygen intake is a measure of cardiorespiratory endurance.

b) Further, it was assumed that when a subject failed to complete a work load due to exhaustion, he had attained his maximal oxygen intake.

## Definition of Terms

a) Maximal oxygen consumption was defined as the rate of oxygen consumption achieved when the circulo-respiratory mechanisms could make no further adjustment to increasing work loads, that is, the mechanisms had reached the limit of their capacity.

b) Cardiorespiratory endurance was the ability of a subject's cardiorespiratory system to adjust in order to sustain bouts of heavy exercise for a specified amount of time.

c) Exercise heart rate was defined as the heart rate taken five seconds before the cessation of each treadmill run.

d) Maximal heart rate was the exercise heart rate associated with the work level at which maximal oxygen intake was achieved.

e) Exhaustion represented the physiological state of the subject at the termination of the test. The author was aware of the psychological implications of the term "exhaustion" but individual maximal oxygen consumption values and appraisal by the experimenters indicated that, in all cases except one, the controlling factor was physiological.

# CHAPTER II

# REVIEW OF THE LITERATURE

## Literature Related to Maximal Oxygen Intake

The physiological meaning of maximal oxygen intake is imperfectly understood. Researchers have failed to reach basic agreement regarding the limiting factors. Cardiac capacity or arterio-venous oxygen difference may be the major controlling factor (58), or as Astrand (3) suggests, pulmonary ventilation, alveolar diffusion rate and the rate of blood flow through the muscles might be regulating factors. Another avenue of possibility could be the high correlation Astrand (3) indicated between blood volume and oxygen intake capacity and the even higher relationship between the latter and total hemoglobin. Robinson (65) has produced evidence which refutes the position that ventilatory capacity and oxygen diffusing capacity are limiting factors in maximal oxygen consumption. In spite of the lack of agreement surrounding maximal oxygen intake, many physiologists consider it to be the best measure of cardiovascular or cardiorespiratory fitness (8, 1, 63, 4).

It must be remembered that the term maximal oxygen intake does not imply an absolute value since it has been shown that an individual may have different oxygen intake values depending upon the nature of the task and the mass of muscle employed. Christensen and Högberg (cited in 58), working with skiers, found that maximal oxygen consumption values were higher for subjects while skiing than for the same subjects running on a treadmill. Taylor, et al (76)

had a subject pump an arm ergometer while running on a treadmill and they reported that the maximal oxygen intake value was 200 ml per minute more than the values for the same subject running on a treadmill. These experiments support the hypothesis that maximal oxygen consumption is specific to the activity and to the functioning muscle mass.

Taylor, Buskirk, and Henschel (76) had as their purpose the description of the method used in their laboratory to study maximal oxygen intake, its limitations, and its usefulness. They were skeptical of procedures used by physiologists because of two factors, motivation and skill. The former became an important factor in tests requiring the subject to run to exhaustion as the end point; the latter, while important in determining a person's response to a fixed task, was not always constant.

Forty-six male volunteers between the ages of 18 - 35 were recruited from the student body at the University of Minnesota. There were large differences in the subjects' ability to run as well as in the body build and composition. The subjects were asked to come to the laboratory for a minimum of three days and occasionally for as many as five days to establish the work loads necessary to produce a maximal oxygen intake. On the first visit the subject performed the treadmill version of the Harvard Fitness Test. The result of this test was used to predict a grade which would yield a maximal oxygen intake.

On the second visit the subject walked at 3.5 miles per

hour, ten per cent grade for ten minutes to one hour. The subject then proceeded, without a rest, to run at seven miles per hour on the grade established the previous day. The length of the run was three minutes. Expired air was collected in the interval one minute and forty-five seconds to two minutes and forty-five seconds.

On the third day the subject ran on an elevation 2.5 per cent higher than the previous day. If the two peak oxygen values differed by less than 150 ml then it was considered that a maximal oxygen intake had been elicited. A return visit was necessary to run at a 2.5 per cent higher grade if the difference was greater than 150 ml.

The authors (76) investigated various test conditions. Alteration of the treadmill speed while keeping the grade constant was not as effective as keeping the speed constant and altering the grade. The reason for this was that certain subjects were not able to run fast enough to keep up with the treadmill therefore they did not reach an oxygen plateau. A speed of six miles per hour was unsatisfactory for some because they "broke stride". Only seven men in 115 subjects failed to reach the criterion established for the plateau of oxygen intake.

Taylor, et al. (76) tested thirteen subjects on several submaximal grades in order to establish a criterion measure. The mean oxygen increment for a 2.5 per cent increase on thirty occasions was 299.3 with a standard deviation of ±86.5 cc/minute. The range was 159 to 470

cc/minute. It was concluded that a difference between two consecutive determinations of 150 cc or less would be a satisfactory criterion which offered little chance of making a mistake in the establishment of a maximal oxygen intake.

Twelve subjects were tested under various experimental conditions, the results of which are to follow. The data demonstrated that a five minute warm-up time is inadequate and that control of environmental temperature is important. A small meal appears to have little effect on the maximal oxygen intake. Small differences in the speed of running and therefore small variations in running style, which result in variations in steps per minute, have little or no effect on the maximal oxygen intake. It was observed that running at zero grade while increasing the speed produced maximal oxygen intakes that were on the average 189 cc/min. smaller than those values produced by raising the grade. The authors attribute this difference to the accessory muscles which come into play in grade running.

Mitchell, Sproule, and Chapman (58) indicated in their paper that the main difficulty with maximal oxygen intake was that its meaning is imperfectly understood. They set out to clarify the meaning of the maximal oxygen intake test by employing arterial and venous catheterization to assess cardiac output, oxygen tension and content, carbon dioxide content and pH. The investigators administered a modified version of the Taylor, Buskirk, Henschel test to

sixty-five normal men ranging in age from twenty to over fifty. Each subject was given a ten minute warm-up at three miles per hour, ten per cent grade. After a ten minute rest the subject ran at six miles per hour, zero per cent grade for 2.5 minutes. Expired gas was collected from one minute and thirty seconds to two minutes and thirty seconds of the run. The subject then rested for ten minutes before running again at 2.5 per cent higher elevation. The procedure was repeated until two consecutive oxygen intakes differed by less than 54 ml.

The researchers found that in seventy-two per cent of the cases when the workload was increased beyond that producing maximal oxygen intake, the value either remained unchanged or declined. The data showed that until a maximal value was reached the oxygen intake rose 142 ± 44 ml with each increase in workload. If the increase was less than 142 minus twice the standard deviation, or 54 ml, the final value was accepted as the maximal intake, the assumption being that the subject had reached a plateau and could not increase very much more. For most individuals the investigators found it unnecessary to progress through all the stipulated elevations because most subjects went to the ten per cent level or beyond. Oxygen intake values sometimes varied erratically at lower workloads, especially in anxious individuals or in those given to hyperventilation.

Mitchell, et al. (58) examined the repeatability of the maximal oxygen intake test by investigating fifteen

subjects in a test-retest situation. The mean value for trial one was 3.06 ± 0.46 liters per minute and for trial two 3.07 ± 0.44 liters per minute. In comparison with the mean value of 3.44 ± 0.46 liters per minute attained by Taylor, Buskirk and Henschel (76) for an age group of 18 - 29 years, Mitchell, Sproule, and Chapman obtained maximal oxygen values of 3.37 ± 0.51 liters per minute for a group which ranged in age from 20 - 29 years. The variance present was almost wholly attributed to the interindividual differences while the random and intraindividual components were virtually negligible. Taylor, et al. (76) found that 18.7 per cent of the variance was random, 80.5 per cent was attributable to interindividual differences and less than one per cent to intraindividual differences.

The authors (58) caution that the determinants of maximal oxygen intake have not been sufficiently clarified to accept it as a test of circulatory capacity with assurance. The term itself should be viewed with skepticism in view of research which has shown that maximal oxygen intake is relative to the task being performed. It was concluded that maximal oxygen intake is dependent on both cardiac output and arterio-venous oxygen difference. "It is probable that in the normal individual the ability to increase cardiac output is the more important of the two factors." (58:546).

Andersen (1:9) stated that in many circles maximal oxygen intake is considered the "best over-all measure of the circulatory and respiratory fitness for work", but he

noted three disadvantages in this measure:

1) It requires extremely hard work to obtain a maximal oxygen intake, thus it would be of little value for diseased patients.
2) The experimental procedures are laborious and time consuming.
3) It has been demonstrated that peak oxygen values depend upon the type of work being performed.

Issekutz, Birkhead and Rodahl (46:47) assert that:

> ...accurate measurement of maximal oxygen uptake is burdened by a number of practical difficulties: a) It is not always easy to decide whether or not the peak value for oxygen uptake has been reached. It requires a maximal effort and this in turn is dependent upon motivation...., b) In the case of untrained subjects it is usually not possible to determine the aerobic capacity in a single experiment, because too high a work load may cause the subject to give up before reaching the maximal oxygen uptake. If, on the other hand, a close-to-maximum work load is applied, repeated attempts may continuously increase his aerobic work capacity because of the training effect.

Slonim, Gillespie and Harold (70) used fifty naval aviation cadets, 18 - 25 years, to calculate maximal oxygen intake. Each day the subject warmed-up for six minutes at 3.5 m.p.h., ten per cent grade, then he walked for six minutes at 3.5 m.p.h. at one of the following grades, 20, 24, 26, and 28 per cent until a level was reached which he could not complete. Then the grade was lowered at steps of one per cent until a test was found which could be completed. In no case was there more than five treadmill

grades. Gas was collected during the sixth minute of exercise. Mean peak oxygen uptake was 4.05 ± 0.39 liters per minute (S.T.P.D.). The range was 3.22 to 5.17 liters per minute. In all but two cases the common symptom of performance limitation was weakness of the lower extremities.

Astrand and Saltin (5) had seven subjects, six males and one female, perform various types of maximal work, one of these being treadmill running. They had each subject run at the speed and grade outlined by Taylor, et al. (76). Each subject warmed-up for ten minutes to an hour after which time he ran at 7 m.p.h. on a predetermined grade until "absolute exhaustion" was reached. Expired air was collected throughout the run, being fractionized into 20 - 60 second samples. The test was repeated on successive days at a 2.5 per cent higher grade each day until the subject's running time was less than two minutes and 45 seconds. The maximal oxygen intake was a few per cent higher in running uphill than in cycling (.05 level). The authors concluded that the aerobic capacity and maximum heart rate are the same in maximal running or cycling, at least in the well-trained subjects.

Astrand and Ryhming (4) are of the opinion that in selecting tests to measure cardiorespiratory fitness one must choose those tasks which involve large muscle groups engaged in relatively high levels of work. They also express the advisability of tests which allow sufficient time for the body systems to adjust to the work. They go

on to say (4:218):

> The individuals capacity (or fitness) for heavy prolonged muscular work will first of all be dependent upon the supply of oxygen to the working muscles. In types of work which engage large groups of muscles the limiting factor for maximal oxygen intake (aerobic capacity) will probably be the capacity and regulation of the oxygen transporting system.

Robinson (65) in his investigations found that a man's maximal oxygen consumption, that is, his maximum aerobic energy release, is obtained in the second or third minute of an exhausing run, "The maximal oxygen consumption is probably the best single physiological indicator of a man's capacity for maintaining extremely heavy work." Robinson points to certain principal physiological factors which he thinks may limit peak oxygen uptake:

1) The rate of oxygen transport by the circulation (dependent upon cardiac output and the oxygen capacity of the blood).
2) The oxygen utilization by the tissues (possibly more limited than 1)).
3) The oxygen diffusing capacity of the lungs.

In discussing the last factor the author suggests good evidence exists that "neither the capacity to ventilate the lungs nor the oxygen difussing capacity of the lungs is a limiting factor in the maximal oxygen consumption of man." Maximal oxygen intake is very constant in any individual, but it may be decreased by extended periods of inactivity and "intensive athletic training" may increase this physio-

logical variable.

Buskirk and Taylor (18) determined the maximal oxygen intake of 46 healthy male students and 13 soldiers in addition to body composition estimates of a) fat-free body weight, b) active tissue, c) body weight, and d) cell mass. All subjects except the soldiers warmed-up on a treadmill for 15 minutes at 3 m.p.h., five per cent grade. The soldiers warmed-up for ten minutes at 3.5 m.p.h. and ten per cent grade. At the end of the warm-up the subject ran for three minutes at 7 m.p.h. on a grade suited to his capacity. The correlations between maximal oxygen intake and a) fat-free body weight, b) active tissue, c) body weight, and d) cell mass were .85, .91, .63, and .45, respectively. The mean maximal oxygen intake was 3.59 liters/minute. The authors concluded that when maximal oxygen consumption is used to examine an individual's capacity for exhausting work it should be expressed in kgm of body weight. If the cardiovascular-respiratory capacity is being measured, then the unit oxygen intake per kgm of fat-free body weight should be used. The point is stressed that "the presence of fat does not interfere with the over-all maximal cardiovascular-respiratory performance as measured by the maximal oxygen intake test."

Damoiseau, et al. (26) express the view that in many instances comparison of maximal oxygen intake results obtained in different laboratories is useless for the simple reason that the different ergometers used have different

characteristics. Coupled with this basic difference, which results in divergent observations, is the means of executing the exercises in different laboratories. They investigated the effects of four types of test modalities; a) constant intensity for a given period, b) short periods of rest between tests preceded by a warm-up, c) progressive intensity tests which are not separated by a rest period, and d) tests which progress in intensity as a function of time, upon three normal subjects riding a bicycle ergometer. The following conclusions were reached:

1) The mean maximal oxygen intake for the exercises with a warm-up was 22 per cent higher than those exercises done on separate days without a warm-up.
2) The exercises which progressed in intensity without rest periods showed a 20 per cent increase over exercises done on successive days with a warm-up.
3) The method of warm-up does not seem to significantly affect the maximal oxygen intake.

Newton (61:164) expressed the opinion that:

> Not only is the maximal oxygen intake the best single physiological indicator of the capacity of a man for sustaining hard work; it is also the most objective measure by which one gains insight into the physical fitness of an individual as reflected by his cardiovascular system.

The author, realizing the existence of many different methods for determining maximal oxygen intake, compared the results of the maximal oxygen intake values of the same group of subjects, 19 - 70 years, on four different tests.

The tests employed were: 1) the Balke test ( with modifications), 2) the Cureton "all out run", 3) a treadmill test with the rate and grade adjusted to the capacity of the individual, 4) a bicycle ergometer test with the brakeload adjusted to the individual's capacity.

The modifications in the Balke test were a treadmill speed of 5.4 kilometers/hour and the subject continued to exhaustion. In the Cureton test gas was collected throughout the entire run at 8.6 per cent grade, ten miles per hour. In the bicycle ergometer test the work load varied for each subject chosen in order to exhaust him in approximately five minutes. After a warm-up of five minutes the subject pedalled at 50 r.p.m. The standard treadmill test was at such a work load that exhausted the subject in three to five minutes.

The highest values were obtained with the Balke test or the standard treadmill run. Maximal oxygen intakes obtained with the bicycle ergometer and with Cureton's test were consistently lower than those obtained with the other two tests except in highly trained subjects. Newton contends that the standard treadmill and Balke tests make use of more realistic work rates and they take into account the initial lag in oxygen consumption by taking several samples throughout the tests. The author failed to indicate the use of any statistical analyses.

Glassford (39) employed 24 healthy, physically active male subjects to compare three commonly used, direct meth-

ods of measuring maximal oxygen consumption and one predicted method. It was reported that the mean maximal oxygen consumption value obtained on the modified Astrand Bicycle Ergometer test was significantly lower ($p<.05$) than that attained on the other three tests. There were no significant differences in the correlation coefficients comparing the various tests.

One notable feature of the maximal oxygen intake test is the repeatability of the maximal oxygen intake values. Taylor, et al. (76) and Buskirk, et al. (18) report reliabilities in a test-retest situation of .95 (28 duplicate determinations) and .98, respectively. Mitchell, Sproule, and Chapman (58) repeated their test on 15 subjects with the following results; the mean for test one was 3.06 liters/minute with a S.D. of ±0.46 ml, the mean for test number two was 3.07 ± 0.44 liters/minute.

## Literature Related to Training and Maximal Oxygen Intake

Knehr, Dill, and Neufeld (48) had 14 young, male subjects, chiefly non-athletic, train at middle distance running for six months. The subjects were tested bi-weekly on performance tests and bi-monthly under resting conditions. The performance tests were given on a treadmill which was elevated to 8.6 per cent grade and a speed of 3.5 m.p.h. After an eight minute warm-up the subjects immediately ran for five minutes or until exhausted. Table I depicts the progressive increases in maximal oxygen intake reported by the authors.

TABLE I

CHANGES IN MAXIMAL OXYGEN INTAKE REPORTED BY KNEHR, DILL AND NEUFELD (48:153)

| Test Interval | Maximal $O_2$ Intake (4 min) | Grade (per cent) | Speed (m.p.h.) |
|---|---|---|---|
| Control | 3.45 | 9.1 | 7 |
| After 2 months | 3.64 | 10.9 | 7 |
| After 4 months | 3.69 | 13.3 | 7 |
| After 6 months | 3.69 | 13.4 | 7 |

The subjects showed a mean increase in maximal oxygen intake of 240 ml per minute over the six month training period. The Table indicates that most of the improvement occurred in the first eight weeks of training.

Robinson and Harmon (63) used nine non-athletic subjects in testing for the effects of training and gelatin upon physiological factors which limit muscular work. The group, ranging in age from 18 - 22 years, trained by running for a 26 week period. Two different grades of aerobic work were employed, one a walking test and the other a running test. At the beginning of training the running test consisted of working at 7 m.p.h., 8.6 per cent grade for five minutes or exhaustion. As a subject was able to complete the five minutes the grade and/or the speed was increased for the next test in an attempt to keep the work severe enough to bring about exhaustion in five minutes. The results showed an 18 per cent increase in maximal oxygen intake at the end of training.

Astrand (3) called attention to the considerable

difference in maximal oxygen consumption between world-class endurance athletes and normal individuals. The difference would seem to indicate that "aerobic capacity is an important factor where fitness for endurance is concerned." A feature of these élite athletes was their ability to consume high quantities of oxygen per kilogram of body weight, 67 ml or better for the 1500 meter men and cross-country skiers compared with an average of 58.6 ml/kg/min for a group of students of the same age. Astrand recorded a maximal oxygen intake of 5.88 liters per minute on a Swedish cross-country skier.

Robinson (65), in support of maximal oxygen consumption as the "best single physiological indicator of a man's capacity for maintaining extremely heavy work", indicated that for a given man it remains reasonably constant except on the occasion of long periods of inactivity. A few months of intensive athletic training can significantly increase this variable. Maximal oxygen consumption, according to Robinson, declines with age, from a mean of 50 ml/kg/min at 18 years to 26 ml/kg/min at 75 years of age.

## Literature Related to Heart Rate

Brouha and Radford (14:199), in reference to pulse rate, argue that "...as a single factor it quite accurately depicts the cardiovascular adjustment of an individual to muscular activity." Bock, et al. (13) arrived at the same conclusion. There are many papers which have

used heart rate as a measure of cardiovascular fitness (72, 21,75,30,42). The general opinion is that training lowers exercise heart rate.

The most logical approach in investigating the reaction of the body to exercise is to determine various variables while an individual is exercising. In comparison with pre- and post-exercise studies there have been, until recently, few investigations that have done this because of technical difficulties of measurement. Taylor (74) concluded in his paper that one should look to responses of the organism which occur during exercise in order to critically evaluate an individual's work capacity and not to recovery. He found that the "time-run" in a maximum test was the most reliable (0.95) of all the measures used in the study, with the heart rate measurements next. Darling (27) views physical fitness as homeostasis and two measures which he feels reflect attempts of the body to maintain homeostasis are maximum pulse rate and blood lactate. A mean maximum heart rate of 195 beats per minute for healthy young men, 18 to 30 years, has been reported in the literature (82, 3, 40). Henderson, et al. (40) recorded a maximum heart rate of 246 by a man performing exhaustive work on a bicycle ergometer. They also concluded that a pulse rate of 180 beats per minute is near the extreme for untrained men. Borgard (52) indicated that in well trained individuals the pulse rate corresponding to maximum performance seldom rises above 180 beats per minute.

Again, Henderson, et al. (40) stated that the resting and exercise pulse rates are slower in athletes than in non-athletes. Taylor (75) corroborated earlier findings that training lowers the pulse rate during work.

## CHAPTER III

## METHODS AND PROCEDURES

Subjects. At the outset of the study 15 prospective University of Alberta varsity hockey players and 13 control subjects were tested before the commencement of hockey practices. Five of the 15 hockey players were released from the team thus leaving the experimental group with 10 subjects. The control group, composed of first year undergraduates and graduate Physical Education Students, was reduced to 10 individuals. The experimental subjects practiced hockey a minimum of five days a week one hour per day until the league schedule began, after which, the practice sessions were reduced to three times per week including two weekend games. The team participated in 26 games throughout the season. The distinguishing factor which differentiated the two groups was that the control subjects, although being intermittently active in most cases, did not participate in a strenuous conditioning program. Table 2 illustrates some physical characteristics of the subjects while the activities of the control group are noted in Table 3.

Initial Treadmill Test. The treadmill test used to determine maximal oxygen consumption was essentially the same as that outlined by Mitchell, Sproule, and Chapman. Two modifications were made. First, the speed was increased to 8 m.p.h. in view of the fact that Mitchell, *et al.* reported (58:539)

In some young normal subjects, maximum oxygen intake

TABLE 2

SOME PHYSICAL CHARACTERISTICS OF THE TWO GROUPS

| HOCKEY | | | | CONTROL | | | |
|---|---|---|---|---|---|---|---|
| Subject | Age Yrs. | Starting Wt. (lbs) | Height (Inches) | Subject | Age Yrs. | Starting Wt. (lbs) | Height (Inches) |
| I. B. | 24 | 184 | 70.0 | B. B. | 26 | 190 | 72.5 |
| T. B. | 23 | 175 | 71.0 | G. C. | 20 | 142 | 71.5 |
| J. F. | 23 | 145 | 69.0 | W. C. | 20 | 170 | 68.5 |
| H. G. | 25 | 183 | 71.0 | L. F. | 20 | 150 | 66.0 |
| R. H. | 24 | 158 | 67.0 | J. G. | 24 | 180 | 71.0 |
| R. J. | 20 | 172 | 69.5 | B. K. | 28 | 190 | 74.5 |
| D. M. | 21 | 169 | 72.0 | W. M. | 25 | 185 | 72.0 |
| D. R. | 23 | 174 | 72.0 | J. M. | 19 | 169 | 70.0 |
| E. W. | 20 | 159 | 71.0 | R. N. | 22 | 158 | 69.0 |
| R. W. | 22 | 190 | 69.0 | J. P. | 19 | 165 | 72.0 |
| Mean | 22.5 | 168.9 | 70.15 | Mean | 22.3 | 169.9 | 70.70 |

TABLE 3

RECREATIONAL ACTIVITIES PARTICIPATED IN BY THE CONTROL SUBJECTS

| SUBJECT | ACTIVITY |
|---|---|
| B. B. (Year 1) | Inactive. |
| G. C. (Year 1) | weight training (5x/wk.), phys. ed. (1 hr./wk.) |
| W. C. (Year 1) | floor hockey, phys. ed. (1 hr./wk.) |
| L. F. (Year 1) | weight training (6x/wk.), handball, squash, phys. ed. (1 hr./wk.) |
| J. G. (Grad) | badminton, hockey |
| B. K. (Grad) | inactive |
| W. M. (Grad) | badminton, hockey |
| J. M. (Year 1) | swimming course, phys. ed. (1 hr./wk.) |
| R. N. (Grad) | badminton, basketball, hockey |
| J. P. (Year 1) | badminton, football, phys. ed. (1 hr./wk.) |

was not reached even at the highest grade possible (14.75 per cent), making it necessary to increase the speed as well as the grade. The highest workload was 9 m.p.h. at 14.75 per cent grade.

Secondly, all subjects were required to run to complete exhaustion instead of stopping when they reached the oxygen criterion established by the author. Watson (80) concluded that the criterion on the Mitchell, Sproule, Chapman test is not applicable when well-trained athletes are employed, the primary reason being that the speed was not fast enough to prevent the subjects from adjusting to submaximal work loads thus eliciting a decreased oxygen intake.

Each subject reported to the laboratory in shorts and running shoes. The subject's weight (shoes removed) was recorded before the telemetering transmitter and electrodes were put in place (Figure III). After walking on the treadmill for 10 minutes at 3.0 m.p.h. and 10 per cent grade the subject rested for 10 minutes on a chair beside the treadmill. During the rest, the headgear and mouthpiece were adjusted to suit the individual. At the 9 minute mark of the rest period a heart rate was taken then the subject mounted the treadmill in preparation for the first run which was performed at 8 m.p.h., 0 per cent grade for 2.5 minutes.

At the one minute and 15 second mark of the run the subject was instructed to insert the mouthpiece. A five second "countdown" preceded the opening of the valve to the Douglas bag at one minute and thirty seconds. The subject placed the nose clamp in position during this period. Expired gas was collected during the last minute of

the run. A heart rate was obtained five seconds before the termination of the exercise. Resting heart rates, recorded with the subject seated, were taken at each minute up to and including the fifth minute of the 10 minute recovery period. A one minute sample of expired gas was collected from the third to the fourth minute of recovery. All the procedures were repeated for each succeeding run except that the grade of the treadmill was increased 2.5 per cent each time. The subjects were tested three times, the first being before the hockey season, the second 7 weeks after the initial test, and the third at the end of the hockey season (21 weeks).

Equipment. The treadmill employed was a Quinton model with a maximum speed of 10 m.p.h. Expired gas was collected in 150 liter Douglas bags enroute from a Modified Otis-McKerrow two-way breathing valve. Eighty-six inches of flexible plastic tubing connected the breathing valve with the Douglas bags. The tubing was 1.5 inches in diameter. Three-way P-321 Thomas valves were used at the junctions of the bags. The gas bags were serially connected by twelve inches of 1.5 inch rubber tubing. Fifty inches of rubber connecting hose joined the main junction with the Dayton evacuating pump (model 2M138), a 1/15 horse power motor supplying the power. Volumes were recorded on an American Meter Company Gasometer (model 802). During each 10 minute rest period the expired gas was immediately analyzed for percentage of oxy-

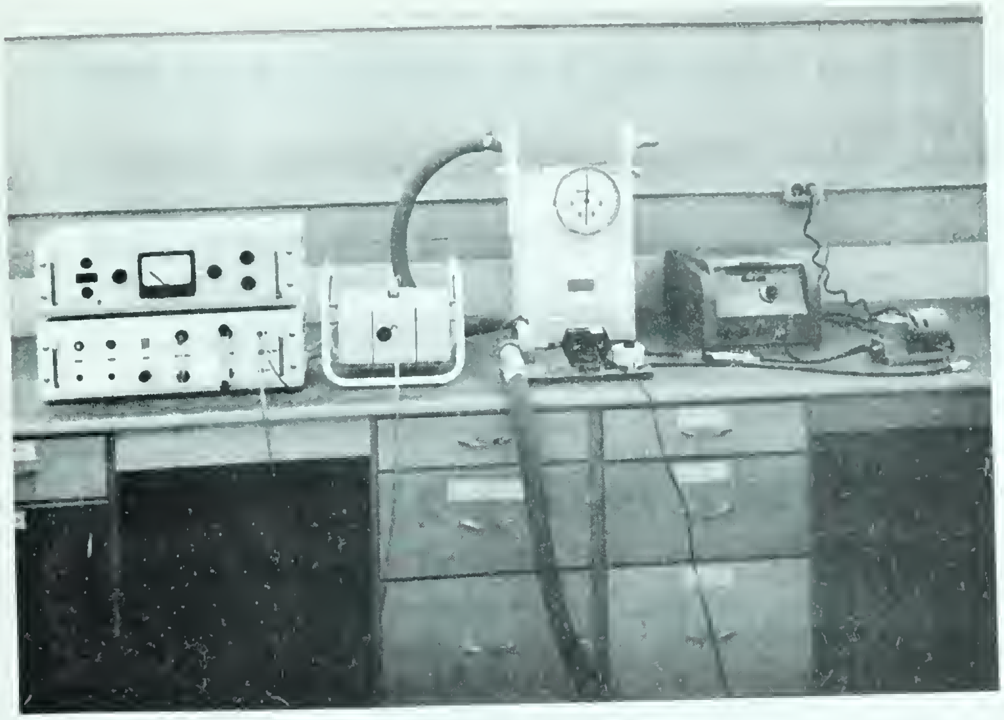

FIGURE I. (left to right).
N.V. Godart $CO_2$ Analyzer,
Volume meter, Beckman E-2
$O_2$ Analyzer

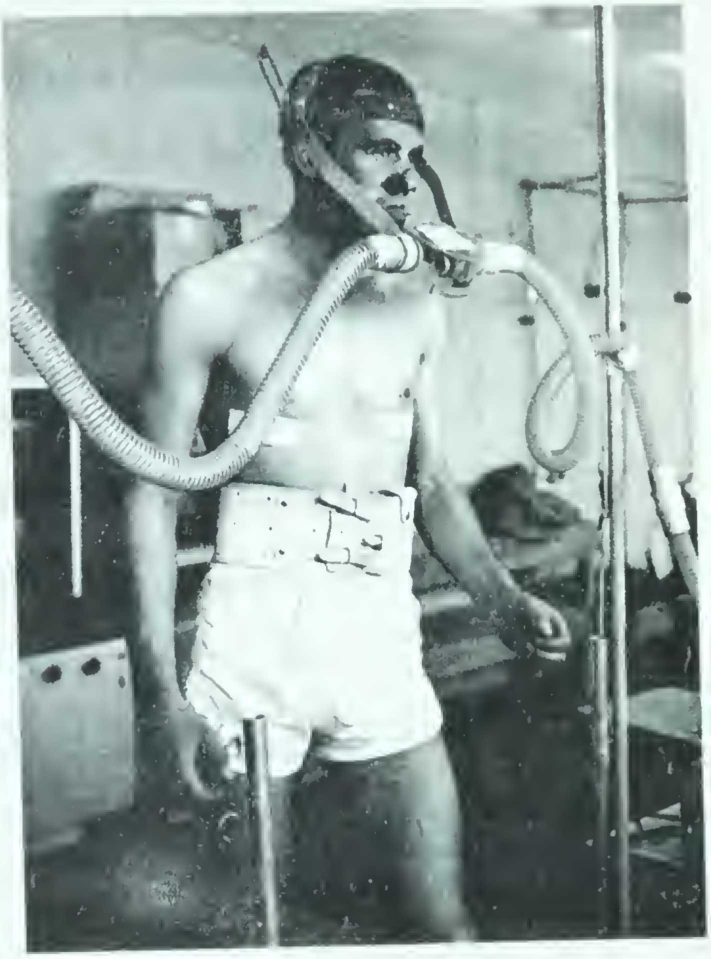

FIGURE III. Otis McKerrow Breathing Valve,
Telemetering Transmitter Belt

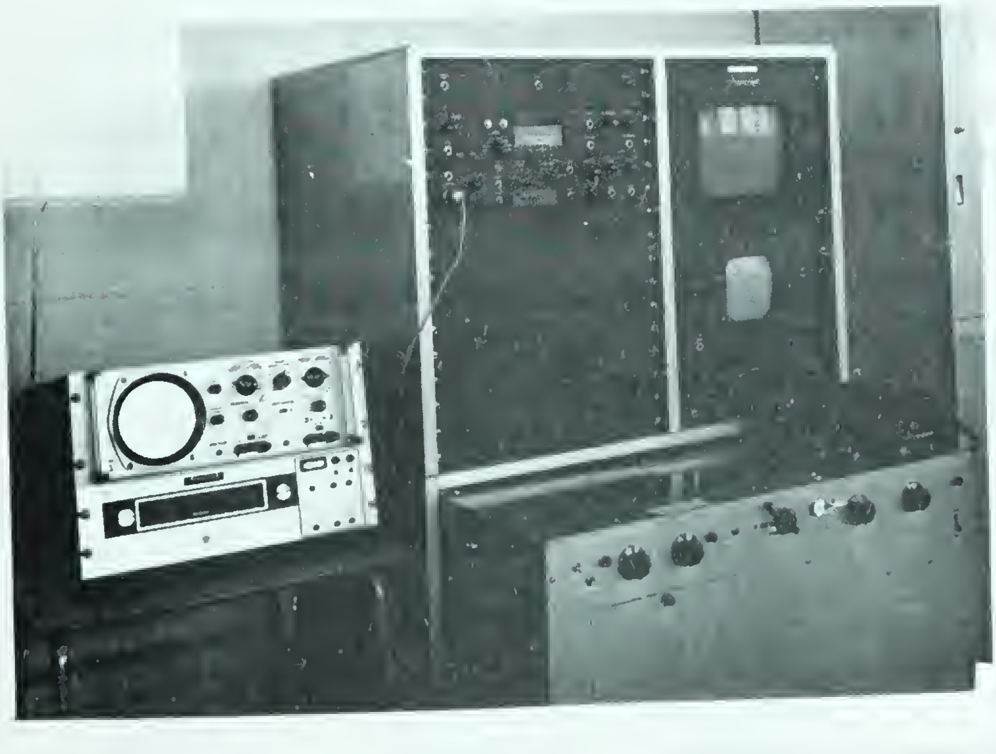

FIGURE II. (left to right)
Hewlett – Packard 120B Oscilloscope,
D–8 Electronics for Medicine Oscilloscope

[illegible]

[illegible]

[illegible]

gen by a Beckman E-2 analyzer and by an N. V. Godart Infrared Capnograph for percentage of carbon dioxide. The analyzers were calibrated daily.

Calculation of Oxygen Intake. In order to determine the inspired volume of oxygen ($V_iO_2$) the following procedure was used. It is based upon the principle of the change in nitrogen content of the expired gas.

1. Determination of the corrected $F_eO_2$

   X $F_eO_2$ x 2.5 (factor for correcting $F_eO_2$ at A.T.P.S. to S.T.P.D.)

2. Determination of $F_eN_2$

   $100 - (F_eO_2 \pm F_eCO_2)$

3. Determination of the corrected $V_e$S.T.P.D.

   $V_e$A.T.P.S. = X liters/minute

   $V_e$S.T.P.D. = $V_e$A.T.P.S. x Factor (to reduce a volume of moist gas to a volume of dry gas at 0° C., 760 mm Hg)

4. Determination of $V_i$S.T.P.D.

   $$V_i\text{S.T.P.D.} = V_e\text{S.T.P.D.} \times \frac{F_eN_2}{F_iN_2}$$

5. Determination of $V_iO_2$

   $V_iO_2$ ($V_i$S.T.P.D. x .2094) - ($V_e$S.T.P.D. x $F_eO_2$) liters/min. where:

| | |
|---|---|
| A.T.P.D. | ambient temperature and pressure dry |
| A.T.P.S. | ambient temperature and pressure saturated |
| S.T.P.D. | standard temperature and pressure dry |
| $V_e$ | volume of expired air |
| $V_i$ | volume of inspired air |
| $F_e$ | per cent of expired |
| $F_i$ | per cent of inspired |

Statistical Analysis. The results of the initial tests were subjected to analysis to determine the significance of the difference between the means for independent samples. The null hypothesis states that there is no difference between the means. The method used is that outlined by Ferguson (33:137). If the variances of the control and experimental groups were significantly different, determined by an F test for independent samples, then the procedure outlined by Ferguson (33:143) was employed. The observations for both groups over the three tests were investigated by the method of trend analysis, described by Edwards (31:227), to determine the significance of the difference between group means, trial means, and an interaction factor. The experimental group was the only one in which all members were able to complete the five per cent elevation for all three tests thus a one-way analysis of variance was applied to the data. The steps involved in this analysis are illustrated in Garrett (38:292). Where significant differences occurred between the groups on the initial test an analysis of covariance (38:296) was used to analyze the data for the initial and final tests.

# CHAPTER IV

## RESULTS AND DISCUSSION

Each of the three testing periods extended over approximately a two week period, thus it was necessary to calculate the average time interval between each test. An average of seven weeks separated the first from the second test and fourteen weeks divided the second from the third test.

### The Effect of Training on Body Weight and Maximal Oxygen Consumption.

Results. FIGURE IV depicts the alterations in body weight of the hockey and control groups. It is evident that both groups decreased in weight, though not significantly, from the first to the second test and the hockey group decreased from the second to the third while the control group returned to approximately its original mean weight. The experimental group underwent greater mean decreases than the control group but the differences were not statistically significant as shown in TABLE 4.

TABLE 4

ANALYSIS OF VARIANCE OF CHANGES IN BODY WEIGHT

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 2.82 | 1 | 2.82 | 0.04 |
| Error (a) | 11,649.37 | 18 | 647.19 | |
| Trials | 43.24 | 2 | 21.62 | 3.04 |
| Groups x Trials | 22.63 | 2 | 11.32 | 1.59 |
| Error (b) | 256.13 | 36 | 7.12 | |
| Total | 11,974.19 | 59 | | |

TABLE 5 shows the percentage increases in maximal oxygen consumption experienced by the hockey and the control

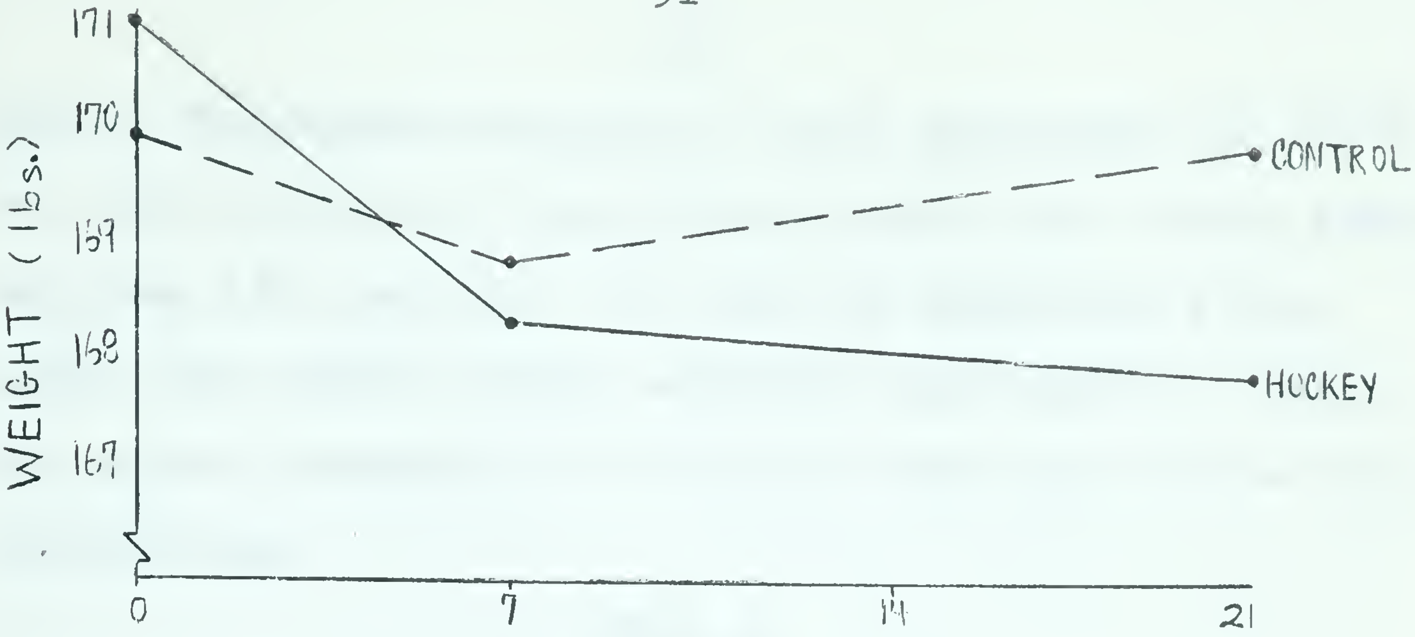

FIGURE IV. CHANGES IN BODY WEIGHT (lbs)

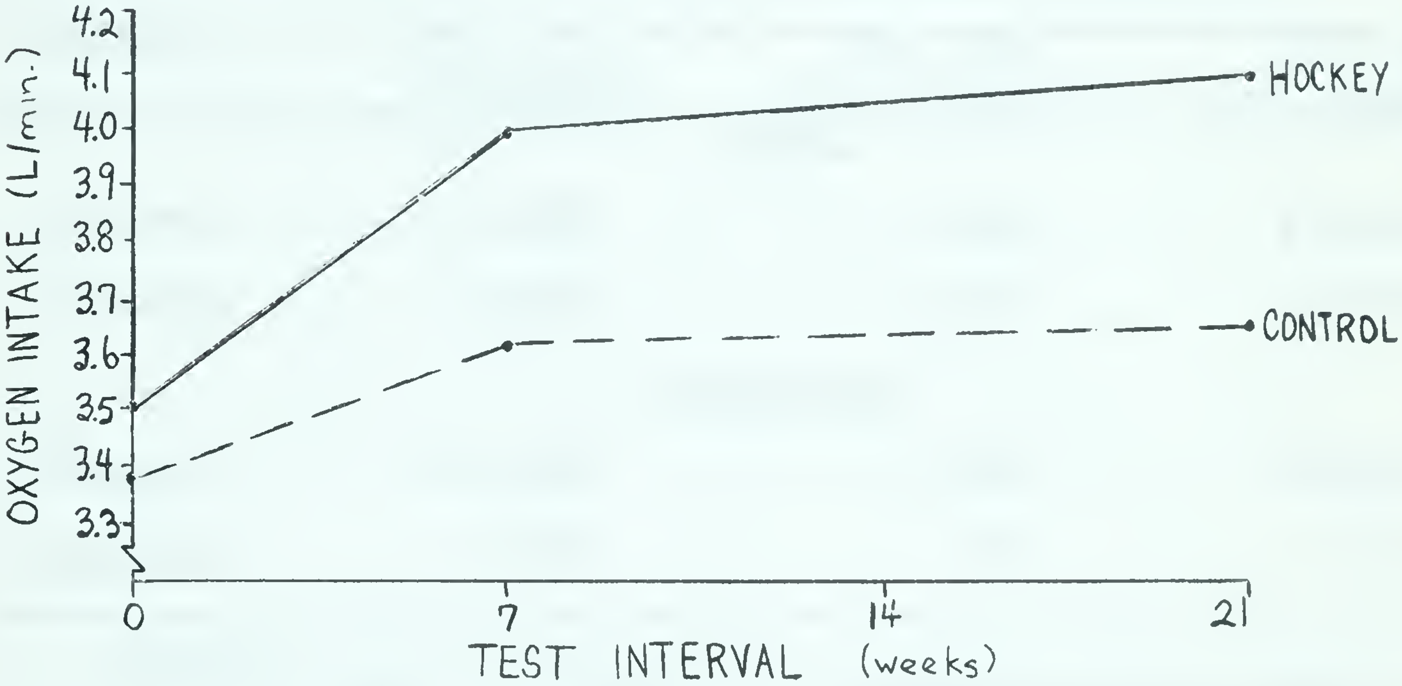

FIGURE V. CHANGES IN MAXIMAL OXYGEN INTAKE (L/min.)

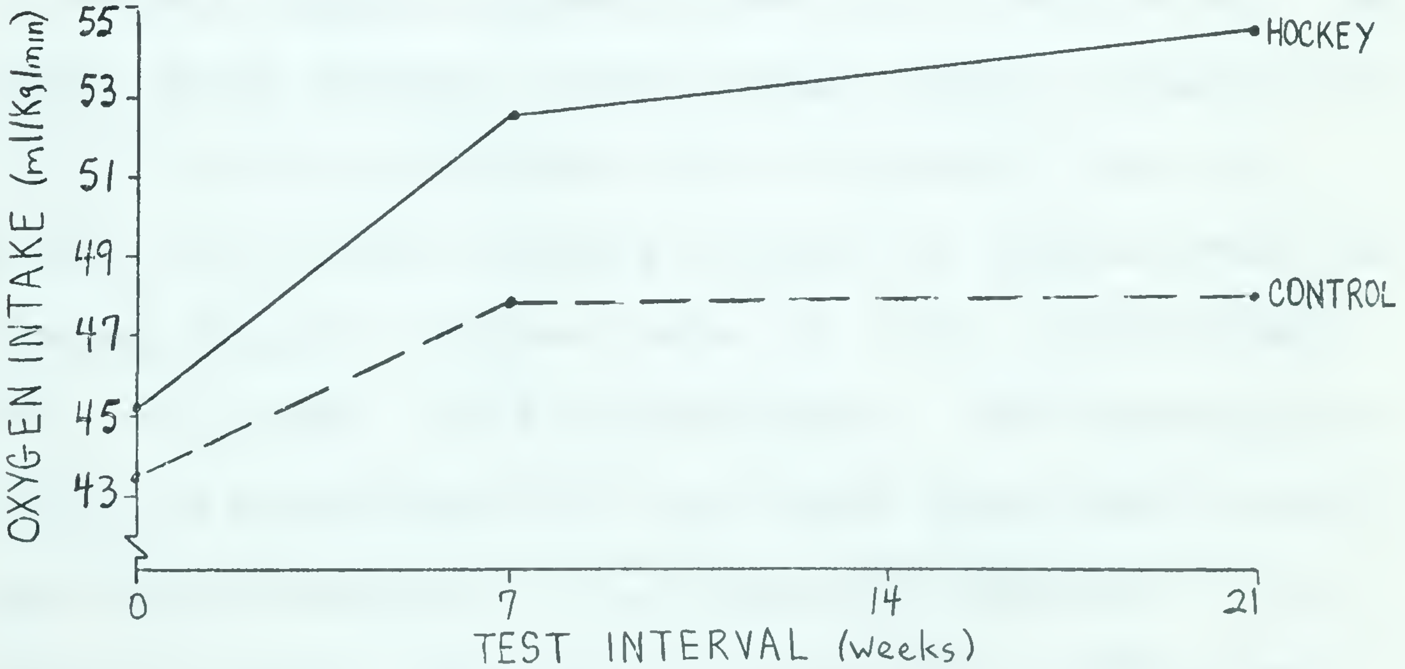

FIGURE VI. CHANGES IN MAXIMAL OXYGEN INTAKE (ml/Kg/min)

group. The hockey group had a total improvement of 17.46 per cent in terms of liters/minute while the control group improved 8.65 per cent. In terms of ml/kg/minute the hockey and control groups exhibited total gains in maximal oxygen consumption of 19.99 per cent and 9.73 per cent respectively.

TABLE 5

PERCENTAGE INCREASES IN MAXIMAL OXYGEN CONSUMPTION

| Group | $T_1 - T_2$ (7 weeks) | $T_2 - T_3$ (14 weeks) | $T_1 - T_3$ (21 weeks) |
|---|---|---|---|
| | | L/min. | |
| Hockey | 13.99% | 2.80% | 17.46% |
| Control | 7.23% | 1.33% | 8.65% |
| | | ml/Kg/min. | |
| Hockey | 16.20% | 3.25% | 19.99% |
| Control | 9.91% | -.17% | 9.73% |

FIGURES V and VI illustrate the changes that resulted in maximal oxygen consumption over a 21 week period. The hockey group reached a mean maximal oxygen consumption of 4.113 ± 0.29 liters/minute from an initial level of 3.510 ± 0.45 liters /minute whereas the control group increased from its original value of 3.376 ± 0.28 liters/minute to 3.668 ± 0.28 liters/minute. The corresponding values in ml/kg/minute for the hockey group and the control group were 45.22 ± 4.12 (initial) and 54.26 ± 5.43 (final), 43.47 ± 7.04 (initial) and 47.70 ± 4.88 (final) respectively.

Tha analysis of variance for the data represented in FIGURES V and VI are shown in TABLES 6 and 7. It may be seen that the difference between the hockey and control groups was significant ($p<.05$) with oxygen consumption expressed in liters/minute but not when expressed as ml/kg/minute. It should be mentioned, however, that this latter difference was significant at the .06 level of confidence. Analysis using the Student-t technique for non-correlated samples revealed that there was no significant difference between the groups initially. This was true regardless of whether the oxygen consumption was expressed as liters/minute or ml/kg/minute. Significant changes ($p<.001$) in maximal oxygen consumption occurred between trials in term of liters/minute and ml/kg/minute (TABLES 6 and 7).

TABLE 6

ANALYSIS OF VARIANCE OF CHANGES IN MAXIMAL OXYGEN CONSUMPTION (L/min)

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 1.52 | 1 | 1.52 | 6.08 * |
| Error (a) | 4.42 | 18 | 0.25 | |
| Trials | 2.32 | 2 | 1.16 | 14.50 *** |
| Groups x Trials | 0.29 | 2 | 0.15 | 1.88 |
| Error (b) | 2.73 | 36 | 0.08 | |
| Total | 11.28 | 59 | | |

* Significant at the .05 level of confidence
***Significant at the .001 level of confidence

Discussion. The hockey group in the present study registered a mean

TABLE 7

ANALYSIS OF VARIANCE OF CHANGES IN MAXIMAL OXYGEN CONSUMPTION (ml/kg/min)

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 277.34 | 1 | 277.34 | 4.17 |
| Error (a) | 1,196.78 | 18 | 66.49 | |
| Trials | 492.70 | 2 | 246.35 | 12.96*** |
| Groups x Trials | 65.06 | 2 | 32.53 | 1.71 |
| Error (b) | 684.27 | 36 | 19.01 | |
| Total | | | | |

*** Significant at the .001 level of confidence

loss in total body weight of 1.41 kg. compared to an average loss of 0.04 kg. for the control subjects, who could be considered intermittently active as a group. It should be remembered, however, that these differences were not significant. Further, it should be mentioned that, in terms of total weight loss, the hockey group lost 13.61 kg. compared to 0.45 kg. for the control group. Thompson, et al. (77) did not observe any significant alterations in mean body weight, as a result of a season of competition, for the hockey and basketball players used in their study. Pascale, et al. (as cited in 77) indicated that paratroopers underwent an average loss of 0.6 kg. as a result of their training program. Kohlrausch (as cited in 77) showed a weight loss of 1.74 kg. for a dog that performed heavy pulling work on a treadmill for several months. It was not determined if the weight changes in the latter two studies were statistically significant.

A second dog, trained by Kohlrausch (as cited in 77),

gained 0.95 kg. after six weeks of treadmill running. Knehr, Dill and Neufeld (48) offered evidence of weight gains as a result of training. The 14 young men that they trained at middle distance running for six months experienced a mean gain of 2.2 kg.

The preceding studies tend to point out the fact that weight changes, resulting from training programs, are very individual; some persons gain weight while others lose it. The subjects used by Thompson, et al. (48) may have experienced little weight loss because of the intensity of the conditioning programs and/or the pre-season state of training of the groups. The paratroopers studied by Pascale, et al. (as cited in 77) might have been in a high state of conditioning before the study was begun therefore there would be little chance for alterations in body weight.

In interpreting the results of Kohlrausch (as cited in 77) and Knehr, et al. (48) it would appear that the work load of the activity played an important role in maintenance of body weight. Weight gains occurred where the work load on the muscles was light and weight loss where it was heavy. Anthropometrical studies (71, 77) have shown that weight loss may not occur during a training program but that an increase in the specific gravity of the muscle mass can occur. In effect a redistribution of weight results.

The precise physiological determinants of alterations in maximal oxygen consumption are, at present, inadequately understood but several investigators (48, 17, 4, 16, 63)

have shown or are of the opinion that training increases the aforementioned parameter. The present experiment corroborated the previous reports both in direction and magnitude (see TABLE 8).

TABLE 8

MEAN MAXIMAL OXYGEN CONSUMPTION OBTAINED BY DIFFERENT RESEARCHERS

| Investigator | Subjects | Age | Mean Max $V_iO_2$(L/min) | Mean Max $V_iO_2$ (ml/kg/min) |
|---|---|---|---|---|
| Astrand and Ryhming (4) | Highly Trained Athletes | 20-30 | 4.15±0.28 | |
| Mitchell, Sproule, Chapman (58) | Untrained Males | 20-43 | 3.37±0.51 | 41.7±3.9 |
| Slonim, Gillespie, Harold (70) | Trained Naval Cadets | 18-25 | 4.05±0.39 | |
| Buskirk, Taylor (18) | Cross-Country Runners | 20.2±1.3 | 4.32±0.35 | 65.8±3.4 |
| Buskirk, Taylor (18) | Intramural Participants | 21.7±2.7 | 3.95±0.43 | 57.5±3.3 |
| Baycroft (11) | Active P.E. Students, Staff, Army Recruits | 17-33 | 3.694±.513 | 48.90±6.52 |
| Watson | Trained Ice Hockey Players | 20-25 | 4.115±0.29 | 54.26±14.90 |
| Watson | Intermittently Active Males | 19-26 | 3.668±0.28 | 47.78±4.77 |

The total percentage increase in maximal oxygen consumption (L/min.) elicited by the hockey group was in accordance with that demonstrated by Robinson and Harmon (63). After six months of middle distance running the nine sub-

jects experienced an 18 per cent increase. However, Knehr, Dill, and Neufeld (48) found only a gain of 6.96 per cent for 14 persons who likewise trained at middle distance running for six months. The latter percentage more closely approximates the improvement (8.65%) which the control subjects underwent in the present experiment. The intensity of the different training programs certainly represents a major factor in accounting for the discrepancy in the previously mentioned percentages. The increases in maximal oxygen consumption experienced by the control group may be attributed to the fact that most of the control subjects became intermittently active after the initial test. As TABLE 3 indicates only two subjects were classed as sedentary.

Initially, the differences that existed in the mean height, weight, and age of both groups were statistically insignificant. Similarly, the absolute and relative maximal oxygen consumption values did not differ significantly. At the completion of the experiment no significant changes had occurred in the mean weight but the maximal oxygen consumption values (L/min) did increase significantly ($p<.001$). It might, therefore, appear that total body weight played an insignificant role in alterations of maximal oxygen consumption. However, Buskirk and Taylor (18) reported a correlation of 0.63 between total body weight and maximal oxygen consumption. It is possible that, although the total body weight of the two groups

did not change, a redistribution of weight might have occured; that is subcutaneous fat could be replaced by active muscle. The additional muscle mass would necessitate an augmented oxygen supply to sustain the newly acquired demands.

When the mean maximal oxygen consumption values were considered in absolute terms (L/min) a significant difference ($p<.05$) existed between the control group and the hockey group. However, when body weight was taken into consideration this significant difference did not exist. Buskirk and Taylor (18:74) have suggested the possibility that differences in maximal oxygen consumption between athletes and normal individuals, found by other investigators, may be accounted for by differences in body composition. The foregoing illustrates the advisability of taking into account the component parts of body weight when comparing different groups with respect to maximal oxygen consumption.

When the maximal oxygen intake values were expressed in ml/kg/minute the difference in total percentage gains between the hockey and control group increased by 1.45 per cent (TABLE 5) while the F ratio decreased (TABLE 7). Although the body weights of the two groups were at no time significantly different, the mean weight of the hockey group was smaller (1.37 kg), thus having larger values in terms of ml/kg/minute. Therefore when percentage gains were calculated the hockey group

demonstrated a greater mean gain, a fact which would lead to the conclusion that the significant difference (F ratio) between the two groups should increase. TABLES 6, 7, 10, 11, 13 and 14 show that this did not occur.

The F ratio, which tests the significance of the overall differences between the groups, is composed of the sum of squares for groups in the numerator and the sum of squares for subjects minus the sum of squares for groups in the denominator.

$$F = \frac{\text{SS Groups}}{\text{SS Subjects} - \text{SS Groups}}$$

The standard deviation of the sum of squares (variance) for the subjects, expressed as a percentage of the overall mean, was considerably larger when body weight was taken into account. In terms of ml/kg/minute the standard deviation represented 79.19 per cent of the overall mean compared to 62.21 per cent for the absolute values. The same method revealed a reduction from 33.67 per cent (L/min) to 27.48 per cent (ml/kg/min) in the per cent standard deviation for the sum of squares for the groups. In view of the above changes in standard deviation, expressed in terms of per cent of the overall mean, it is evident that the F ratio would decrease.

The difference in maximal oxygen consumption between the hockey and control groups was not statistically significant in terms of ml/kg/minute, however, this does not eliminate the possibility that the difference was physio-

logically significant. Any group that demonstrates a 10.26 per cent greater maximal oxygen consumption must certainly have a decided physiological, if not statistical, advantage in terms of cardiorespiratory endurance.

Changes in Heart Rate Contingent Upon Maximal Oxygen Consumption.

Results. FIGURE VII shows the changes that occurred in the mean heart rate associated with the maximal oxygen consumption values for each of the three tests. The mean heart rate for the hockey group decreased from 192.2 beats/minute on the initial test to 185.3 beats/minute on the final test. The control group experienced a rise from 191.6 beats/minute on the initial test to 194.2 beats/minute on the second test and a decrease on the third test to 187.5 beats/minute. A consistent decrease occurred in the mean heart rates of the hockey group. TABLE 9 reveals that the overall changes cited above were not statistically significant but the differences between trials were significant ($p<.01$).

Discussion. One feature of the heart rate associated with maximal oxygen consumption was that as the latter increased (FIGURES V, VI) the former decreased. It might perhaps be deduced that the cardiac output must have increased to compensate for the reduced heart rate, that is, more blood was circulated per stroke (S.V.) than when the heart beat faster in the untrained state (13,15,48). However, Balke (7) cautions that cardiac output is a compli-

## TABLE 9

## ANALYSIS OF VARIANCE OF CHANGES IN HEART RATE CONTINGENT UPON ATTAINMENT OF MAXIMAL OXYGEN CONSUMPTION

| Source of Variance | Sum of Squares | d.f. | Mean Square | F |
|---|---|---|---|---|
| Groups | 170.02 | 1 | 170.02 | 0.84 |
| Error (a) | 3,639.57 | 18 | 202.20 | |
| Trials | 311.04 | 2 | 155.52 | 5.62 ** |
| Groups x Trials | 217.23 | 2 | 108.62 | 3.92 * |
| Error (b) | 996.73 | 36 | 27.69 | |
| Total | 5,334.59 | 59 | | |

* Significant at the .05 level of confidence
**Significant at the .01 level of confidence

cated variable because of the interrelationship of stroke volume, heart rate, and arterio-venous oxygen difference.

Asmussen and Neilsen (2) reaffirm the view of Brouha (15) that in heavy exercise the stroke volume reaches a constant level. They reported that it reaches a maximal value at a heart rate of about 120 beats/minute and then levels off or decreases, thus any further increase in cardiac output must be dependent upon the heart rate and/or the arterio-venous oxygen difference. Alterations in the hemoglobin content of the blood may have played an important role in the increased maximal oxygen consumption. Mitchell, Sproule, and Chapman (58) place major emphasis on the role of the cardiac output and the arterio-venous oxygen difference as limiting factors in maximal oxygen consumption.

The highest heart rate recorded in the present experiment was 214 beats/minute which is below the 246 beats/

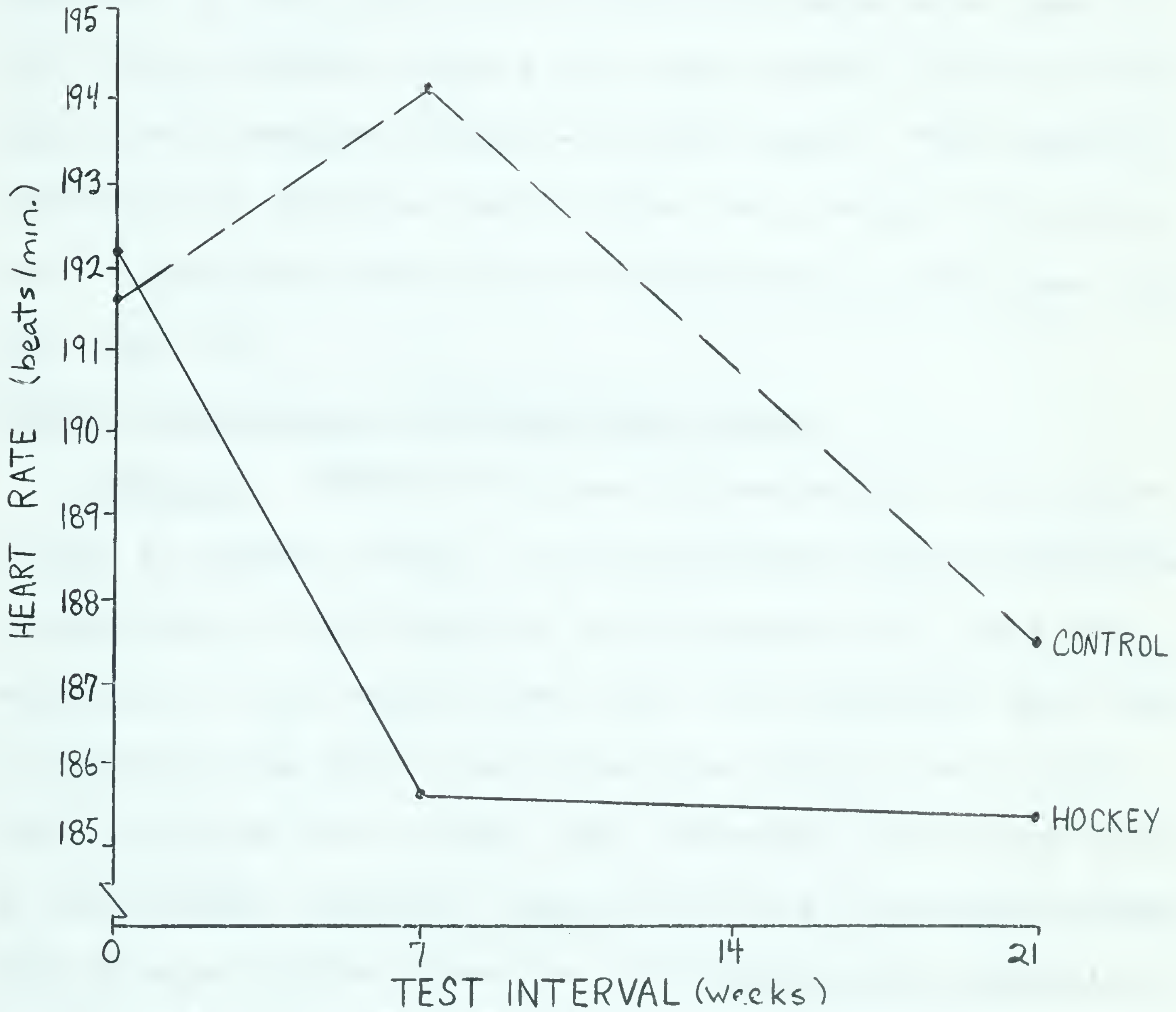

FIGURE VII. HEART RATE CONTINGENT UPON ATTAINMENT OF MAXIMAL $O_2$

minute recorded by Henderson (40). The literature (82, 3, 41) supports 180 beats/minute as a mean maximal heart rate for males between the ages of 18 - 30 years compared to a mean maximal value of 189 beats/minute for men 19 - 28 years old in the present study. The difference can be explained, in part, by the fact that athletes were used in the former studies whereas the mean maximal value in this paper is a combined athlete-control value. The observed reduction in exercise heart rates, as a result of training and intermittent activity is in accordance with other findings (40, 75).

### Oxygen Consumption for Given Work Loads.

Results. FIGURES VIII and IX demonstrate the alterations in oxygen intake, in liters/minute and ml/kg/minute respectively, that occurred in the groups for three elevations, 0, 2.5, and 5.0 per cent. All subjects were able to complete the first two elevations but the only group able to finish the 5.0 per cent grade was the hockey group. As the FIGURES indicate comparisons have been made between both groups for the first two elevations only; analysis of the third elevation was performed solely on the hockey group.

TABLE 10 reveals that at zero per cent grade, eight miles per hour, there was no significant difference between the groups in average oxygen consumption over the three tests. Similarly, no significant difference appeared between the groups in terms of ml/kg/minute (TABLE 13).

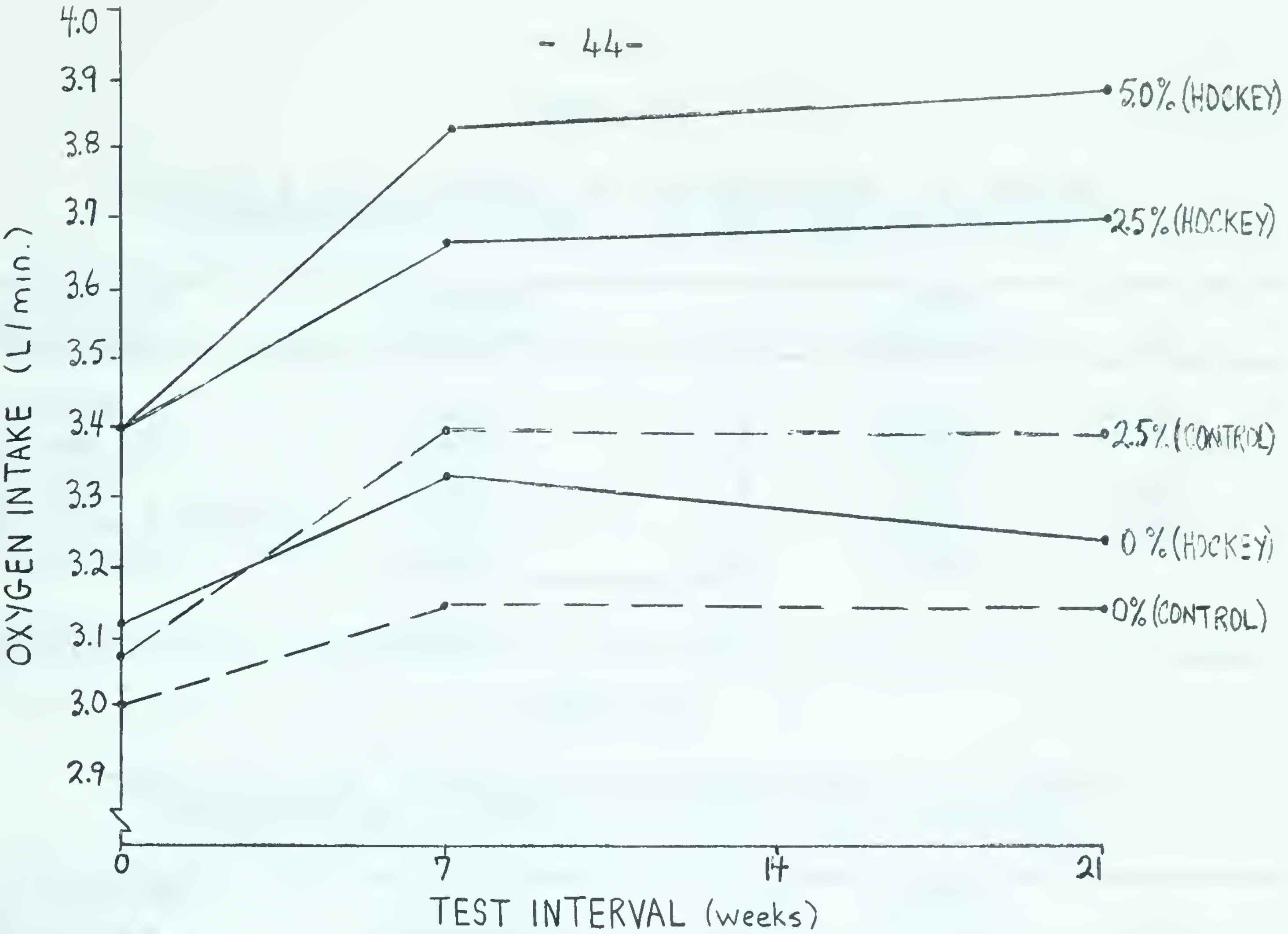

FIGURE VIII. OXYGEN INTAKE (L/min) DURING EXERCISE AT THREE ELEVATIONS

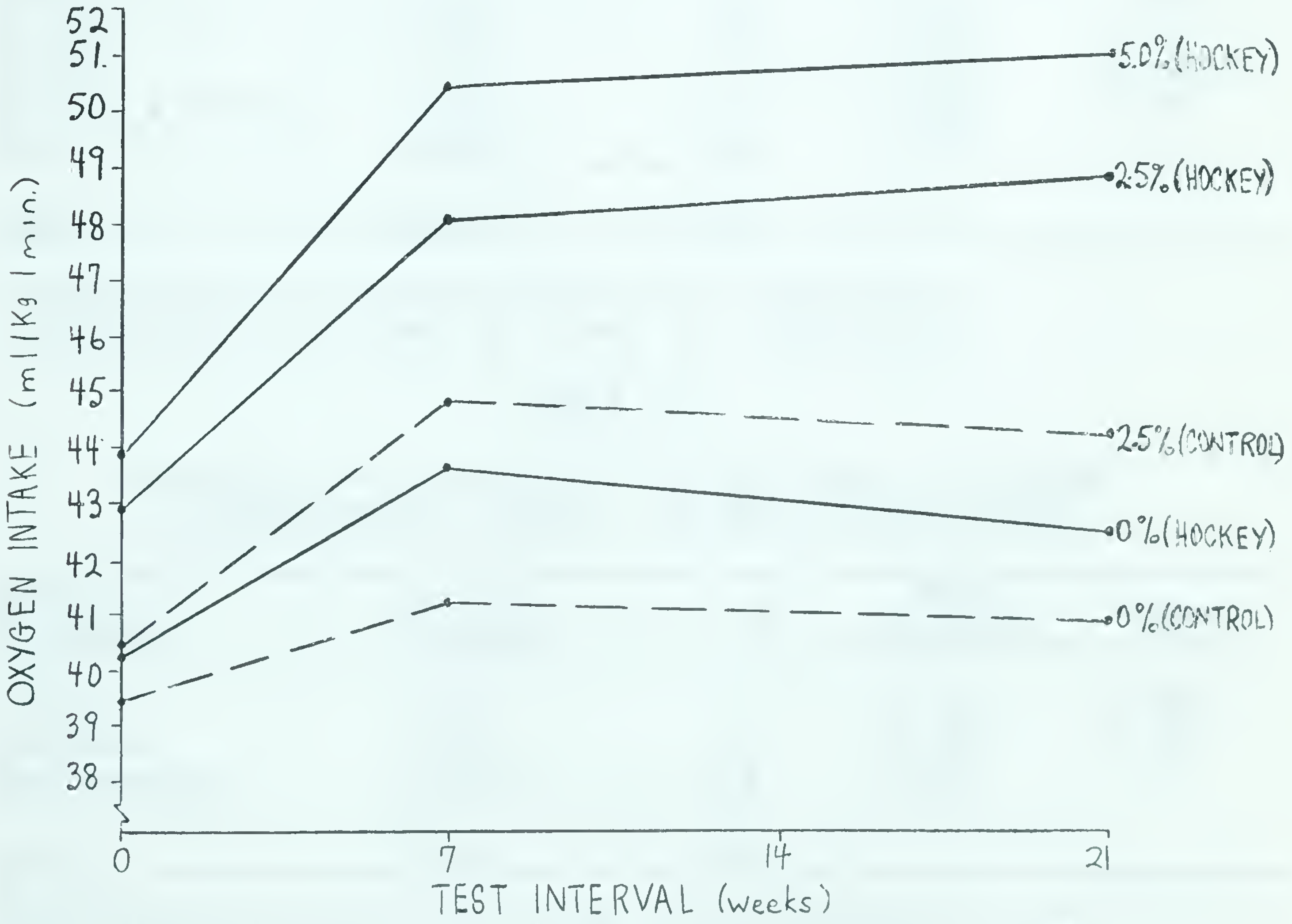

FIGURE IX. OXYGEN INTAKE (ml/Kg/min) DURING EXERCISE AT THREE ELEVATIONS

## TABLE 10

## ANALYSIS OF VARIANCE OF ALTERATIONS IN OXYGEN CONSUMPTION (L/MIN.) AT THE 0% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 0.24 | 1 | 0.24 | 0.96 |
| Error (a) | 4.58 | 18 | 0.25 | |
| Trials | 0.30 | 2 | 0.15 | 1.67 |
| Groups x Trials | 0.04 | 2 | 0.02 | 0.22 |
| Error (b) | 3.17 | 36 | 0.09 | |
| Total | 8.33 | 59 | | |

## TABLE 11

## ANALYSIS OF VARIANCE OF ALTERATIONS IN OXYGEN CONSUMPTION (L/MIN.) AT THE 2.5% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 1.38 | 1 | 1.38 | 4.93* |
| Errors (a) | 5.09 | 18 | 0.28 | |
| Trials | 1.27 | 2 | 0.64 | 8.00** |
| Groups x Trials | 0.00 | 2 | 0.00 | 0.00 |
| Error (b) | 2.79 | 36 | 0.08 | |
| Total | 10.53 | 59 | | |

* Significant at the .05 level of confidence
**Significant at the .01 level of confidence

## TABLE 12

## ANALYSIS OF VARIANCE OF ALTERATIONS IN OXYGEN CONSUMPTION (L/MIN.) AT THE 5% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Trials | 1.47 | 2 | 0.74 | 5.26* |
| Subjects | 2.33 | 9 | 0.26 | 1.86 |
| Interaction | 2.59 | 18 | 0.14 | |
| Total | 6.39 | 29 | | |

*Significant at the .05 level of confidence

## TABLE 13

### ANALYSIS OF VARIANCE OF ALTERATIONS IN OXYGEN CONSUMPTION (ml/kg/min.) AT THE 0% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 37.50 | 1 | 37.50 | 0.73 |
| Error (a) | 923.51 | 18 | 51.31 | |
| Trials | 125.21 | 2 | 62.61 | 4.76* |
| Groups x Trials | 7.04 | 2 | 3.52 | 0.27 |
| Error (b) | 473.27 | 36 | 13.15 | |
| Total | 1,566.53 | 59 | | |

*Significant at the .05 level of confidence

## TABLE 14

### ANALYSIS OF VARIANCE OF ALTERATIONS IN OXYGEN CONSUMPTION (ml/kg/min.) AT THE 2.5% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 217.62 | 1 | 217.62 | 4.30 |
| Error (a) | 911.53 | 18 | 50.64 | |
| Trials | 260.39 | 2 | 130.20 | 7.27** |
| Groups x Trials | 4.31 | 2 | 2.16 | 0.12 |
| Error (b) | 644.54 | 36 | 17.90 | |
| Total | 2,038.39 | 59 | | |

**Significant at the .01 level of confidence

## TABLE 15

### ANALYSIS OF VARIANCE OF ALTERATIONS IN OXYGEN CONSUMPTION (ml/kg/min.) AT THE 5% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Trials | 430.49 | 2 | 215.25 | 11.39*** |
| Subjects | 332.13 | 9 | 36.90 | 1.95 |
| Interaction | 340.13 | 18 | 18.90 | |
| Total | 1,102.75 | 29 | | |

***Significant at the .001 level of confidence

Increasing the work load to 2.5 per cent resulted in a significant difference ($p < .05$) between the two groups for the absolute mean oxygen intake values (TABLE 11) but not in terms of ml/kg/minute (TABLE 14). The mean oxygen consumption for both groups was not significantly different at the commencement of the experiment. TABLES 12 and 15 depict significant differences ($p < .05$ and $p < .001$ respectively) between trials at the 5 per cent elevation for the experimental group.

Discussion. FIGURES VIII and IX illustrate the fact that the hockey group had higher mean oxygen consumption values than the control group at submaximal work levels although the differences were not statistically significant at least in terms of ml/kg/minute. The general concept that training results in an increased efficiency must not be misconstrued as meaning a reduction in oxygen consumption in the achievement of a particular, submaximal task. Some physiological variables, such as exercise heart rate (FIGURES VII and X), do decrease as a result of training or intermittent activity but submaximal oxygen consumption is one parameter that increases. Brouha and Radford (14) state that training increases mechanical efficiency, that is, a reduction in oxygen intake for a given work load. FIGURES VIII and IX would seem to be contradictory to this but such is not the case. Reduction in oxygen consumption, as alluded to by Brouha and Radford (14), implies a diminution of the total oxygen costs of a given task (exercise

oxygen + recovery oxygen - basal metabolic rate). Training appears to lead to an increase in the rate of oxygen consumption during exercise and an accompanying reduction in recovery oxygen consumption. The basal metabolic rate generally increases slightly with training.

TABLES 10, 11, 12 and 13 indicate the same phenomenon, with regard to a decrease in the F ratio for the differences between groups, as shown in TABLES 5 and 6. The explanation for this converse relationship is again probably due to the differences in the variances. Since no significant differences occurred, even in L/minute between the groups at the zero per cent elevation, it would appear that the work load was not sufficiently strenuous to discriminate between the hockey group and the control group. In considering the parameters investigated, this suggests the possibility that strenuous training programs do not produce alterations which lead to significantly superior performances at the lower end of the submaximal work scale.

### Maximal Exercise Heart Rates for Three Elevations.

Results. FIGURE X depicts the changes in peak exercise heart rates that occurred during the three trials for the three elevations 0, 2.5, and 5.0 per cent. At the zero per cent grade the control group had mean exercise heart rate values of 184.5, 180.4, and 177.9 recorded from the first to the last test respectively. Corresponding values for the hockey group were 169.5, 163.9, and 168.6. TABLE 16 reveals that there was a significant difference ($p < .01$)

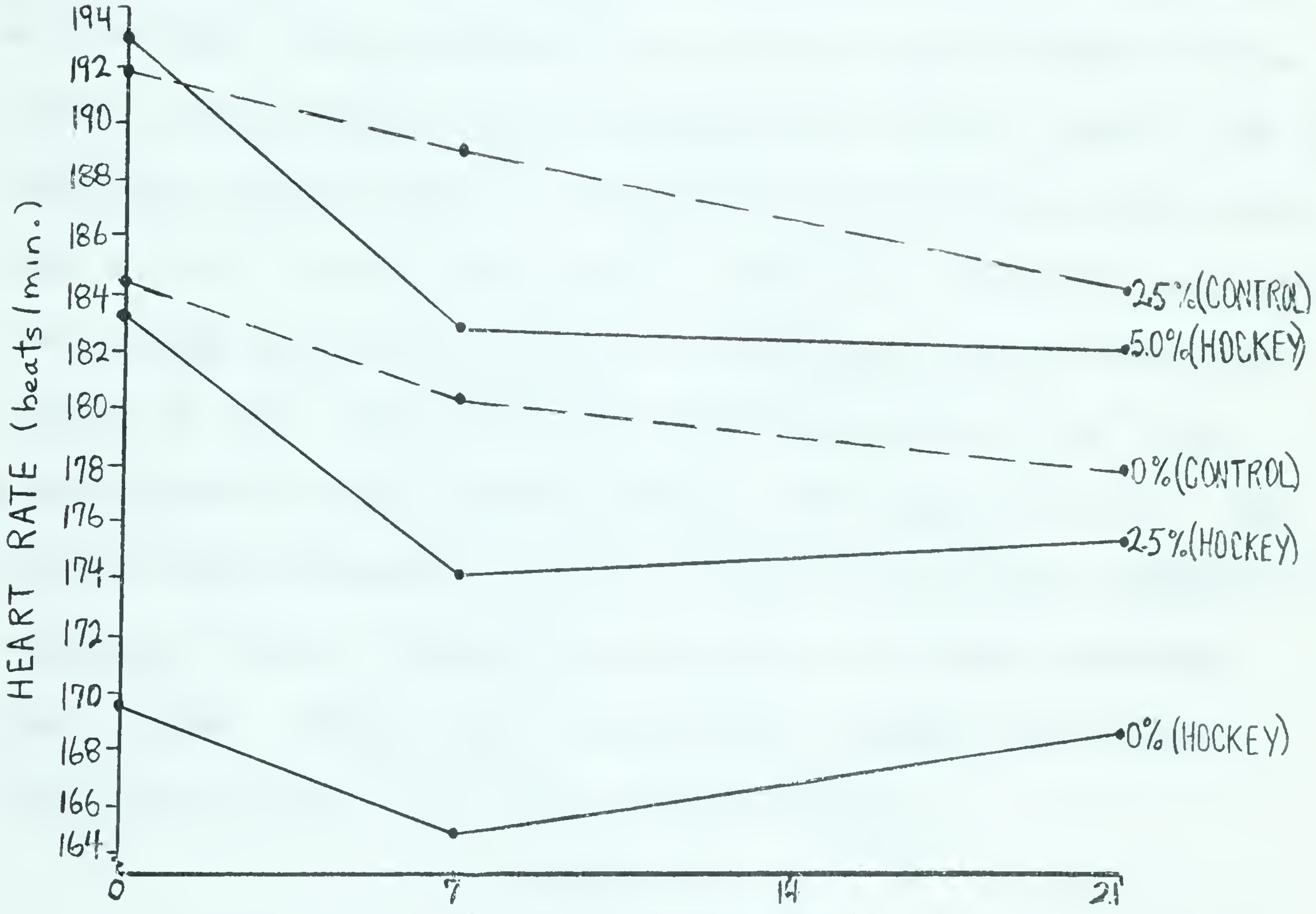

FIGURE X. CHANGES IN MAXIMAL EXERCISE HEART RATE FOR THREE ELEVATIONS

between the groups in the overall average exercise heart rate for the zero per cent grade, but the Student - t technique for non-correlated samples indicated that the groups differed significantly at the .001 confidence level on the initial test.

The following quantities represented the average exercise heart rate values at the 2.5 per cent level for the control and hockey groups respectively: 191.9, 189.1, 184.3 and 183.2, 174.2, 175.5. Significant differences for heart rate at the 2.5 per cent level, appeared (TABLE 17) between the groups at the .01 level of confidence and between the trials at the .05 confidence level but the initial differences were again significantly different ($p < .001$). The hockey group achieved, at the 5.0 per cent level (FIGURE X), values of 193.0, 182.8, and 182.3 for the mean exercise heart rates. There was a difference between the trials (TABLE 18) at the .01 level of confidence.

TABLE 16

ANALYSIS OF VARIANCE OF MAXIMAL EXERCISE HEART RATE FOR 0% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Group | 2,640.07 | 1 | 2,640.07 | 11.80** |
| Error (a) | 4,025.86 | 18 | 223.66 | |
| Trials | 222.30 | 2 | 111.15 | 1.19 |
| Groups x Trials | 118.63 | 2 | 59.32 | .63 |
| Error (b) | 3,369.74 | 36 | | |
| Total | 10,376.60 | 59 | | |

** Significant at the .01 level of confidence

TABLE 17

ANALYSIS OF VARIANCE OF MAXIMAL EXERCISE HEART RATE FOR 2.5% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Groups | 1,749.61 | 1 | 1,749.61 | 9.90** |
| Error (a) | 3,180.39 | 18 | 176.69 | |
| Trials | 642.64 | 2 | 321.32 | 6.76* |
| Groups x Trials | 126.09 | 2 | 63.05 | 1.33 |
| Error (b) | 1,711.21 | 36 | 47.53 | |
| Total | 7,409.94 | 59 | | |

* Significant at the .05 level of confidence
**Significant at the .01 level of confidence

TABLE 18

ANALYSIS OF VARIANCE OF MAXIMAL EXERCISE HEART RATE FOR 5% ELEVATION

| Source of Variance | Sum of Squares | df | Mean Square | F |
|---|---|---|---|---|
| Trials | 729.27 | 2 | 364.64 | 8.44** |
| Subjects | 703.63 | 9 | 78.18 | 1.81 |
| Interaction | 778.07 | 18 | 43.23 | |
| Total | 2,210.97 | 29 | | |

**Significant at the .01 level of confidence

Since the mean heart rates differed initially at the zero and 2.5 per cent levels, analyses of covariance (38: 296) were computed to determine if the final mean heart rates, for both levels, were significantly different. Covariance analysis is a statistical procedure which holds the effects of initial scores constant in order to determine the significance of the differences in final scores. TABLES 19 and 20 present the covariance analyses. It can be seen from these tables that the final mean heart rates

for the hockey and the control group were not significantly different at either elevation.

### TABLE 19

### ANALYSIS OF COVARIANCE OF THE CHANGES IN MAXIMAL EXERCISE HEART RATE FOR ZERO PER CENT ELEVATION

| Source of Variation | df | SSx | SSy | SSy.x | MSy.x(Vy.x) | Fy.x |
|---|---|---|---|---|---|---|
| Among Means | 1 | 1125 | 432.4 | 207.8 | 207.8 | 1.66 |
| Within Groups | 17 | 3689 | 2187.3 | 2126.0 | 125.1 | |
| Total | 18 | 4815 | 2619.7 | 2333.9 | | |

### TABLE 20

### ANALYSIS OF COVARIANCE OF THE CHANGES IN MAXIMAL EXERCISE HEART RATE FOR 2.5 PER CENT ELEVATION

| Source of Variation | df | SSx | SSy | SSy.x | MSy.x(Vy.x) | Fy.x |
|---|---|---|---|---|---|---|
| Among Means | 1 | 378.45 | 387.20 | 108.32 | 108.32 | 1.57 |
| Within Groups | 17 | 2280.50 | 1560.60 | 1131.43 | 66.56 | |
| Total | 18 | 2658.95 | 1947.80 | 1239.75 | 68.88 | |

Discussion. It is evident, in comparing FIGURE X with FIGURES VIII and IX, that the mean heart rates decreased as the mean oxygen consumption went up. The converse of this was true for the hockey group at the zero per cent elevation. A possible explanation for the latter phenomena is that the hockey group had a few days rest at the completion of the hockey season before being tested. Brouha (16) stated that the rate at which losses in cardiorespiratory function occur is proportional to the rate at which the gains occurred. This explanation does not hold true for the maximal heart rate and maximal oxygen consumption relationship (Figures V, VI, VII) but the inten-

sity of the work loads may be the reason for the inconsistency. The interpretation which was given for the relationship between the maximal parameters is applicable in explaining the relationship between the heart rate and oxygen consumption at the zero and 2.5 per cent elevation.

Significant differences ($p < .01$) occurred between the groups with respect to the heart rates with the hockey group having the lower mean values. The analysis of covariance indicated that the final mean values were not significantly different. It is likely that the initial differences were, in part, due to the presence of more unfit subjects, with respect to higher exercise heart rates, in the control group than in the hockey group. It is also likely that, since all of the experimental subjects had previous experience with the treadmill, some of the difference in the initial heart rates was due to nervous excitation on the part of the control group. Balke (10), however, feels that any increment in pre-exercise heart rate due to anticipation would have little effect on heart rates at higher work loads.

General Discussion. All the figures concerned with oxygen consumption and heart rate show that the greatest changes occurred during the first seven weeks of the ice hockey training program. There may be a practical implication here, in that, if the major alterations in oxygen consumption and heart rate are made in the first

seven weeks, perhaps, from this point on, more emphasis could be placed upon the development or improvement of skills and less on conditioning. Before this implication can be considered worthwhile at least two assumptions must be made:

1) Oxygen consumption and heart rate as measured by treadmill performance are directly related to oxygen consumption and heart rate during performance in ice hockey.

2) Maximal oxygen consumption (cardiorespiratory endurance) and heart rate, with its attendant implications, are the most important considerations in conditioning for ice hockey.

These assumptions are open for criticism but the matter should be investigated further before they are discarded as being untenable or false.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

The primary aim of this study was to investigate the changes in maximal oxygen consumption which occurred over a season of ice hockey. The secondary purposes were to ascertain the alterations which occurred in body weight and its relationship to oxygen consumption, submaximal exercise oxygen consumption, and submaximal exercise heart rate.

An experimental group of ten University of Alberta varsity hockey players, ranging in age from 20 - 25 years, and a control group of ten intermittently active undergraduate and graduate students, ranging in age from 19 - 28 years, participated in the study which covered a 21 week period. The maximal oxygen consumption procedure outlined by Mitchell, Sproule, and Chapman (58) was used to measure the oxygen consumption and heart rates on the pre-season, mid-season, and end-of-the-season tests.

The test for homogeneity of variance, as described by Ferguson (33:227) indicated that, of the variables investigated, only the initial variances for the heart rates of the hockey and control group were significantly different at the zero per cent ($p<.001$) and 2.5 per cent ($p<.001$) level. In this instance, differences in initial means were tested by the Cochran-Cox method for significant differences between means having unequal variances. The t test for non-correlated samples (33:141) showed that none of the other means were significantly different at the outset of the experiment. At the 5.0 per cent elevation

a two-way analysis of variance (38:292) was employed to test the differences between the trial means of the hockey group.

The trend analysis of variance (3-Way), as illustrated by Edwards (31:227), was used to test the significance of the differences between the means of the groups and the trials. This technique was used to analyze all the variables except the submaximal exercise heart rates. Significant differences ($p < .001$) occurred between the trials (both groups combined) but there was no significant difference between the groups when maximal oxygen consumption was considered in terms of ml/kg/minute. Significant differences ($p < .05$) did occur between the groups and trials when maximal oxygen consumption was expressed in terms of liters/minute. There was no real difference between the groups in maximal heart rates associated with the attainment of maximal oxygen consumption but the trials were significantly different ($p < .001$). At the zero per cent elevation no significant differences occurred in oxygen consumption. At the 2.5 per cent elevation significant differences occurred between the trials ($p < .001$) and between the groups but only in terms of liters/minute. The 5.0 per cent elevation revealed that a real difference existed between the trials both in terms of liters/minute ($p < .05$) and ml/kg/minute ($p < .001$). Analysis of covariance (38:296) revealed that, at the zero and 2.5 per cent grades, there were no significant differ-

ences between the final mean heart rate values of the two groups, even when the effects of the initial values were eliminated. The total body weight of the two groups was not significantly different.

The following conclusions appear to be justified within the limitations of the statistical techniques employed and the population investigated.

1. The season of ice hockey significantly increased the maximal oxygen consumption of the hockey group over that of the control group when expressing it in terms of liters/minute.

2. There was no significant difference in the maximal oxygen consumption of the hockey group compared to that of the control group when expressing it in terms of ml/kg/minute.

3. The maximal heart rates of both the experimental and the control group decreased significantly over the 21 week period but the difference between the two groups was not significant.

4. The hockey group exhibited no superiority over the control group in submaximal oxygen consumption at the zero per cent elevation.

5. The oxygen consumption for the hockey group at the 2.5 per cent elevation was significantly higher than that of the control group in terms of liters/minute but not in terms of ml/kg/minute. There were highly significant differences between the trials.

6. The hockey group exhibited a significant increase in oxygen consumption between the trials for the 5.0 per cent elevation.

7. The difference that existed between the submaximal heart rates of the hockey group and the control group could not be attributed to the ice hockey training program.

8. It is important that body weight be taken into consideration when investigating maximal oxygen consumption.

9. Intermittent activity can increase maximal oxygen consumption and decrease maximal heart rate associated with maximal oxygen consumption.

10. There was no significant change in the mean body weight of the two groups over the 21 week period.

## Recommendations

1. Further study should be attempted to determine the period at which the major factors in cardiorespiratory endurance reach a plateau. Such knowledge may be of practical importance in determining the aspects to be emphasized at various intervals during a season training.

2. Since it is speculated in the present study that cardiac output may have increased as a result of training, a similar study involving the direct measurement of cardiac output should be attempted.

3. The relationship of basal metabolic rate to maximal oxygen consumption and recovery oxygen consumption

would be a worthwhile study.

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# APPENDIX

# APPENDIX A

# STATISTICAL TREATMENT

## STATISTICAL TREATMENT

Study Design. Two groups of subjects composed of 10 subjects each were subjected to three maximal oxygen intake tests, the interval between the first and second tests being seven weeks and the interval between the second and third tests 14 weeks. All subjects were able to complete the 0 per cent and 2.5 per cent elevations of the test on all occasions while the subjects in the hockey group were able to complete, in addition, the 5.0 per cent elevation. The following comparisons were made:

1. A comparison between the two groups for maximal oxygen intake.
2. A comparison between the two groups for heart rates associated with maximal oxygen consumption.
3. A comparison between the two groups for oxygen consumption and for heart rates at the zero per cent elevation.
4. A comparison between the two groups for oxygen consumption and for heart rates at the 2.5 per cent elevation.
5. Comparisons among the subjects of the hockey group for oxygen consumption and for heart rates at the 5.0 per cent elevation.
6. A comparison of the alterations in total body weight.

### Statistical Procedure.

Testing variances for independent samples.

1. $S_1^2 = \frac{N_1 \Sigma X_1^2 - (\Sigma X_1)^2}{N_1(N_1-1)}$ (33:141)

2. $S_2^2 = \frac{N_2 \Sigma X_2^2 - (\Sigma X_2)^2}{N_2(N_2-1)}$ (33:141)

3. $F = \frac{S_1^2 \text{ (larger)}}{S_2^2 \text{ (smaller)}}$ (33:141) where

| | |
|---|---|
| $S_1^2$ | variance of experimental group |
| $S_2^2$ | variance of control group |
| $N_1$ | number of observations in experimental group |
| $N_2$ | number of observations in control group |
| $F$ | variance ratio |

### Testing Means for independent samples (equal variances)

1. $S^2 = \frac{(N_1-1)S_1^2 + (N_2-1)S_2^2}{(N_1-1) + (N_2-1)}$ (33:137)

2. $t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(S^2/N_1) + (S^2/N_2)}}$ where

| | |
|---|---|
| $S^2$ | combined variance |
| $S_1^2$ | variance of experimental group |
| $S_2^2$ | variance of control group |
| $X_1$ | mean of experimental group |
| $X_2$ | mean of control group |
| $N_1$ | number of observations in experimental group |
| $N_2$ | number of observations in control group |

### Testing Means for independent samples (unequal variances.

$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{S_{\bar{x}1}^2 + S_{\bar{x}2}^2}}$ (33:143) where

| | |
|---|---|
| $X_1$ | mean of the experimental group |
| $X_2$ | mean of the control group |

$$t_{05} = \frac{S_{\bar{x}1}{}^2 t_1 + S_{\bar{x}2}{}^2 t_2}{S_{\bar{x}1}{}^2 + S_{\bar{x}2}{}^2} \quad (33:144)$$

$S_{\bar{x}1}{}^2$ variance of the mean of the experimental sampling distribution

$S_{\bar{x}1}{}^2$ variance of the mean of the control sampling distribution

$t_1$ and $t_2$ required values for appropriate degrees of freedom.

Trend Analysis of Maximal $O_2$(L/min.). The trend analysis, as described by Edwards (31:227), was used to test the significance of the differences for all the variables except submaximal exercise heart rates. An example of the method is illustrated below.

| | Subject | Pre | Mid | End | | |
|---|---|---|---|---|---|---|
| | B. B. | 3.319 | 3.158 | 3.581 | 10.058 | |
| | G. C. | 3.173 | 3.173 | 3.164 | 9.510 | |
| C | W. C. | 3.037 | 3.593 | 3.256 | 9.886 | |
| O | L. F. | 3.537 | 3.602 | 3.390 | 10.529 | |
| N | J. G. | 3.307 | 3.631 | 3.975 | 10.913 | |
| T | B. K. | 3.431 | 3.530 | 3.491 | 10.452 | |
| R | W. M. | 2.976 | 3.802 | 3.972 | 10.750 | |
| O | J. M. | 3.460 | 3.381 | 3.834 | 10.675 | |
| L | R. N. | 3.474 | 4.107 | 3.628 | 11.209 | |
| | J. P. | 4.041 | 4.221 | 4.392 | 12.654 | |
| | X | 33.755 | 36.198 | 36.683 | 106.636 | $X^2$ 1143.820 |
| | $X^2$ | 114.77 | 132.14 | 135.21 | 382.95 | |
| | I. B. | 3.659 | 3.790 | 3.966 | 11.415 | |
| | T. B. | 3.784 | 3.804 | 4.040 | 11.628 | |
| H | J. F. | 2.951 | 3.569 | 4.335 | 10.855 | |
| O | H. G. | 3.722 | 4.233 | 4.074 | 12.029 | |
| C | R. H. | 3.376 | 3.993 | 4.146 | 11.515 | |
| K | R. J. | 3.753 | 3.898 | 4.369 | 12.020 | |
| E | D. M. | 2.604 | 4.589 | 3.409 | 10.602 | |
| Y | D. R. | 3.673 | 3.668 | 4.055 | 11.396 | |
| | E. W. | 3.183 | 4.183 | 4.105 | 11.471 | |
| | R. W. | 4.303 | 4.285 | 4.627 | 13.215 | |
| | X | 35.008 | 40.012 | 41.126 | 116.146 | $X^2$ 1355.560 |
| | $X^2$ | 124.672 | 161.001 | 170.043 | 455.92 | |
| | X | 68.763 | 76.210 | 77.809 | 222.782 | |
| | | | | $X^2$ | 838.47 | |

Sums of Squares.(SS)

1) Correction term (C.T.) $= \frac{222.782^2}{60} = 827.19$

2) Total SS $= (3.319^2 + 3.173 + \ldots + 4.627^2) - \text{C.T.}$

$= 11.28$

3) Subject SS $= 1/3(10.058^2 + 9.510^2 + \ldots + 13.215^2) - \text{C.T.}$

$= 5.94$

4) Trial SS $= 1/20(68.76^2 + 76.21^2 + 77.81^2) - \text{C.T.}$

$= 2.32$

5) Subjects x Trials SS

$= 11.28 - (594 + 2.32)$

$= 3.02$

Degrees of Freedom.

Total = 59

Subjects = $19\begin{cases} 1 \text{ groups} \\ 18 \text{ Residual} \end{cases}$

Trials = 2

Subject x Trials = $38\begin{cases} 2 \text{ groups} \\ 36 \text{ Residual} \end{cases}$

Partitioning SS (Subjects).

SS (groups) = $1/30(106.636^2 + 116.146^2) - \text{C.T.}$

1.52

Residual = SS (Subjects) - SS (groups)

$= 5.94 - 1.52$

$= 4.42$

Partitioning SS (Subjects x Trials).

TABLE B

| | Trials | | |
|---|---|---|---|
| Groups | $B_1$ | $B_2$ | $B_3$ |
| $A_1$ | 33.755 | 36.198 | 36.683 |
| $A_2$ | 35.008 | 40.012 | 41.126 |

SS (subjects x trials) can be partitioned into

A. groups x trials = 2 degrees of freedom (d.f.)

B. Residual = 36 degrees of freedom

SS (between cells in TABLE B)

$= 1/10(33.755^2 + 35.008^2 + \ldots + 41.126^2) - \text{C.T.}$

$= 4.13$

SS (groups x trials) = SS (cells) - SS (groups) - SS (trials)

$= 4.13 - (1.52 + 2.32)$

$= 0.29$

SS (subjects x trials) = SS (groups x trials) + Residual

Residual = SS (subjects x trials) - SS (groups x trials)

$= 3.02 - 0.29$

$= 2.73$

Analysis (Trend).

| Source of Variance | SS | d.f. | M.S. | F |
|---|---|---|---|---|
| Groups | 1.52 | 1 | 1.52 | 6.08 |
| Error (a) | 4.42 | 18 | 0.25 | |
| Trials | 2.32 | 2 | 1.16 | 14.50 |
| Groups x Trials | 0.29 | 2 | 0.15 | 1.88 |
| Error (b) | 2.73 | 36 | 0.08 | |
| Total | 11.28 | 59 | | |

Analysis of Covariance (Heart Rate - Zero Per Cent). The analysis of covariance technique outlined by Garrett 38:296) was used to test the significances of the submaximal exercise heart rates.

1) Correction terms: $\frac{3540^2}{20} = \underline{626,580}$ (C.Tx)

$\frac{3465^2}{20} = \underline{600,311.3}$ (C.Ty)

$$\frac{3540 \times 3465}{20} = \underline{613,305} \quad \text{(C.T.xy)}$$

2) Total SS : For x $= 631,394 - 626,580$

$= \underline{4,814}$

For y $= 602,931 - 600,311.3$

$= \underline{2619.7}$

For xy $= 614,478 - 613,305$

$= \underline{1,173}$

3) Among Group Means SS

For x $= \dfrac{1845^2 + 1695^2}{10} - \text{C.Tx}$

$= 627,705 - 626,580 \quad = \quad \underline{1125}$

For y $= \dfrac{1779^2 + 1686^2}{10} - \text{C.Ty}$

$= 600,743.7 - 600,311.3 \quad = \quad \underline{432.5}$

For xy $= \dfrac{1845 \times 1779 \quad 1695 \times 1686}{10} - \text{C.Txy}$

$= 614,002.5 - 613,305.0 \quad = \quad \underline{697.5}$

4) Within Groups SS

For x $= 4,814 - 1125 \quad = \quad \underline{3689}$

For y $= 2619.7 - 432.4 \quad = \quad \underline{2187.3}$

For xy $= 1173 - 697.5 \quad = \quad \underline{475.5}$

5) Analysis of Variance of X and Y scores taken separately.

| Source of Variation | df | $SS_x$ | $SS_y$ | $M.Sx(V_x)$ | $M.Sy(V_y)$ |
|---|---|---|---|---|---|
| Among Means | 1 | 1125 | 432.4 | 1125 | 432.4 |
| Within Groups | 18 | 3689 | 2187.3 | 204.9 | 121.5 |
| Total | 19 | 4814 | 2619.7 | | |

$$Fx = \frac{1125}{204.9} = 5.49$$

$$Fy = \frac{432.4}{121.5} = 3.56$$

6) Computation of Adjusted SS for y: i.e., SS y.x

$$\text{Total SS} = 2619.7 - \frac{(1173)^2}{4814} = \underline{2333.85}$$

$$\text{Within SS} = 2187.3 - \frac{(475.5)^2}{3689} = \underline{2126.01}$$

$$\text{Among Mean's SS} = 2333.85 - 2126.01 = \underline{207.84}$$

ANALYSIS OF COVARIANCE

| Source of Variation | df | SSx | SSy | SSyx | MSy.x(Vy.x) | F |
|---|---|---|---|---|---|---|
| Among Means | 1 | 1125 | 432.4 | 207.84 | 207.84 | 1.66 |
| Within Groups | 17 | 3689 | 2187.3 | 2126.01 | 125.06 | |
| Total | 18 | 4814 | 2619.7 | 2333.85 | | |

# APPENDIX B

# RAW DATA SHEET

# MAX. $V_iO_2$ TEST

NAME ______________
HEIGHT ______________
WEIGHT ___|___|______
AGE ______________

| | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| B.P. | | | |
| Temp. | | | |
| Factor | | | |

T.M. SPEED ___ m.p.h.

| | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| DATE | | | |

| GRADE % | HEART RATES | | | | | | | GAS ANALYSIS | | | | | | MAX $V_iO_2$ | REC. $O_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EXERCISE | | RECOVERY (MINS). | | | | | PEAK EXERCISE | | | RECOVERY | | | | |
| | Prior | Peak | 1 | 2 | 3 | 4 | 5 | $\%O_2$ | $\%CO_2$ | VOL | $\%O_2$ | $\%CO_2$ | VOL | | |
| 0 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 2.5 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 5.0 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 7.5 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 10.0 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 12.5 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| 15.0 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

# APPENDIX C

# RAW DATA

# OXYGEN CONSUMPTION FOR THE HOCKEY GROUP

| Sub- | | TEST I | | TEST II | | TEST III | |
|---|---|---|---|---|---|---|---|
| ject | Gr. | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) |
| I.B. | 0.0% | 3.371 | 40.39 | 3.653 | 44.74 | 3.558 | 44.82 |
| | 2.5% | 3.659 | 43.84 | 3.790 | 46.42 | 3.677 | 46.32 |
| | 5.0% | 3.496 | 41.89 | 3.620 | 44.34 | 3.966 | 49.96 |
| | 7.5% | | | | | 3.932 | 49.53 |
| T.B. | 0.0% | 2.781 | 35.03 | 3.373 | 43.48 | 3.402 | 44.12 |
| | 2.5% | 3.313 | 41.74 | 3.514 | 45.30 | 3.583 | 46.46 |
| | 5.0% | 3.576 | 45.05 | 3.679 | 47.43 | 3.960 | 51.36 |
| | 7.5% | 3.784 | 47.67 | 3.804 | 49.04 | 4.040 | 52.39 |
| | 10.0% | | | 3.164 | 40.79 | 4.018 | 52.11 |
| J.F. | 0.0% | 2.951 | 44.87 | 3.162 | 47.92 | 2.928 | 44.52 |
| | 2.5% | 2.935 | 44.63 | 3.098 | 46.95 | 3.812 | 57.96 |
| | 5.0% | 2.793 | 42.47 | 3.569 | 54.08 | 3.744 | 56.93 |
| | 7.5% | | | 3.483 | 52.78 | 4.335 | 65.91 |
| H.G. | 0.0% | 3.494 | 42.09 | 3.143 | 39.15 | 3.368 | 41.71 |
| | 2.5% | 3.572 | 43.03 | 3.752 | 46.73 | 4.059 | 50.27 |
| | 5.0% | 3.722 | 44.84 | 3.962 | 49.35 | 4.074 | 50.46 |
| | 7.5% | 3.420 | 41.20 | 4.233 | 52.72 | 3.960 | 49.05 |
| | 10.0% | | | 3.807 | 47.42 | | |
| R.H. | 0.0% | 3.206 | 44.73 | 3.158 | 44.63 | 3.229 | 44.49 |
| | 2.5% | 3.376 | 47.11 | 3.787 | 53.52 | 3.927 | 54.11 |
| | 5.0% | 3.256 | 45.43 | 3.993 | 56.43 | 4.146 | 57.12 |
| | 7.5% | | | 3.727 | 52.67 | 3.777 | 52.04 |
| R.J. | 0.0% | 3.541 | 45.39 | 3.217 | 42.09 | 3.406 | 44.30 |
| | 2.5% | 3.616 | 46.35 | 3.645 | 47.69 | 3.404 | 44.27 |
| | 5.0% | 3.753 | 50.40 | 3.590 | 46.97 | 4.184 | 54.42 |
| | 7.5% | 3.653 | 48.10 | 3.898 | 51.00 | 4.369 | 56.82 |
| | 10.0% | | | | | 3.848 | 50.05 |
| D.M. | 0.0% | 2.004 | 26.14 | 3.196 | 41.94 | 2.003 | 26.93 |
| | 2.5% | 2.597 | 33.88 | 3.720 | 48.81 | 2.928 | 39.36 |
| | 5.0% | 2.522 | 32.90 | 4.342 | 56.97 | 3.095 | 41.61 |
| | 7.5% | 2.604 | 33.92 | 4.482 | 58.81 | 3.365 | 45.24 |
| | 10.0% | | | 4.589 | 60.22 | 3.409 | 45.83 |
| | 12.5% | | | 3.731 | 48.96 | 1.181 | 15.88 |
| D.R. | 0.0% | 3.196 | 40.49 | 3.431 | 43.47 | 3.717 | 45.52 |
| | 2.5% | 3.673 | 46.54 | 3.668 | 46.47 | 4.034 | 49.41 |
| | 5.0% | 3.514 | 44.52 | 3.367 | 42.66 | 4.055 | 49.66 |
| E.W. | 0.0% | 2.716 | 37.66 | 3.524 | 49.17 | 3.292 | 46.82 |
| | 2.5% | 2.993 | 41.50 | 3.833 | 53.48 | 3.693 | 52.53 |

| Subject | Gr. | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) |
|---|---|---|---|---|---|---|---|
|  | 5.0% | 3.183 | 44.14 | 4.006 | 55.90 | 3.172 | 44.26 |
|  | 7.5% |  |  | 4.183 | 58.37 | 4.105 | 58.38 |
|  | 10.0% |  |  | 4.135 | 57.70 | 3.694 | 52.54 |
| R.W. | 0.0% | 3.942 | 45.74 | 3.406 | 40.37 | 3.552 | 43.02 |
|  | 2.5% | 4.303 | 49.93 | 3.897 | 46.19 | 3.955 | 47.91 |
|  | 5.0% | 3.986 | 46.25 | 4.285 | 50.79 | 4.627 | 56.04 |
|  | 7.5% |  |  | 4.057 | 48.09 | 3.890 | 47.12 |

## OXYGEN CONSUMPTION FOR THE CONTROL GROUP

| Subject | Gr. | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) |
|---|---|---|---|---|---|---|---|
| B.B. | 0.0% | 3.319 | 38.51 | 2.943 | 34.79 | 2.848 | 34.98 |
| | 2.5% | 3.218 | 37.34 | 3.158 | 37.33 | 3.286 | 40.36 |
| | 5.0% | | | 3.115 | 36.82 | 3.581 | 43.98 |
| G.C. | 0.0% | 2.903 | 45.07 | 2.912 | 45.21 | 2.481 | 38.25 |
| | 2.5% | 3.101 | 48.15 | 3.095 | 48.05 | 2.810 | 43.32 |
| | 5.0% | 3.173 | 49.26 | 3.173 | 49.26 | 3.164 | 48.77 |
| | 7.5% | | | | | 2.716 | 41.86 |
| W.C. | 0.0% | 2.876 | 37.30 | 3.089 | 40.53 | 2.845 | 37.00 |
| | 2.5% | 3.073 | 31.60 | 3.142 | 41.23 | 3.214 | 41.80 |
| | 5.0% | 2.970 | 38.52 | 3.593 | 47.15 | 3.200 | 41.62 |
| | 7.5% | 2.844 | 36.88 | 3.578 | 46.95 | 3.256 | 42.35 |
| L.F. | 0.0% | 3.203 | 47.08 | 2.977 | 44.35 | 3.082 | 46.53 |
| | 2.5% | 3.228 | 47.44 | 3.360 | 50.05 | 3.123 | 47.15 |
| | 5.0% | 3.537 | 51.98 | 3.602 | 53.66 | 3.390 | 51.19 |
| | 7.5% | | | 3.526 | 52.53 | 3.293 | 49.72 |
| J.G. | 0.0% | 3.307 | 40.50 | 3.295 | 41.28 | 3.547 | 42.38 |
| | 2.5% | 1.970 | 24.13 | 3.556 | 44.55 | 3.975 | 47.50 |
| | 5.0% | 1.881 | 23.04 | 3.631 | 45.48 | 3.594 | 42.94 |
| | 7.5% | | | 3.620 | 45.35 | | |
| B.K. | 0.0% | 2.700 | 31.33 | 3.278 | 37.44 | 3.298 | 37.67 |
| | 2.5% | 3.229 | 37.47 | 3.530 | 40.32 | 3.491 | 39.87 |
| | 5.0% | 3.431 | 39.81 | 3.406 | 38.90 | 3.421 | 39.08 |
| W.M. | 0.0% | 2.313 | 27.56 | 3.384 | 40.77 | 3.242 | 38.22 |
| | 2.5% | 2.976 | 35.46 | 3.475 | 41.86 | 3.279 | 38.66 |
| | 5.0% | | | 3.802 | 45.80 | 3.972 | 46.83 |
| | 7.5% | | | 3.433 | 41.36 | 3.558 | 41.95 |
| J.M. | 0.0% | 3.254 | 42.45 | 2.898 | 36.72 | 3.395 | 43.52 |
| | 2.5% | 3.460 | 45.13 | 3.381 | 42.84 | 3.834 | 49.14 |
| | 5.0% | 3.161 | 41.23 | 3.328 | 42.16 | 3.551 | 45.51 |
| R.N. | 0.0% | 2.814 | 39.26 | 2.992 | 43.11 | 3.157 | 44.05 |
| | 2.5% | 3.159 | 44.08 | 3.337 | 48.08 | 3.539 | 49.38 |
| | 5.0% | 3.194 | 44.57 | 3.575 | 51.51 | 3.486 | 48.64 |
| | 7.5% | 3.474 | 48.47 | 3.994 | 57.55 | 3.628 | 50.62 |
| | 10.0% | | | 4.107 | 59.18 | | |
| J.P. | 0.0% | 3.423 | 45.74 | 3.686 | 49.55 | 3.526 | 46.55 |
| | 2.5% | 3.951 | 52.79 | 3.986 | 53.58 | 3.468 | 45.78 |
| | 5.0% | 3.989 | 53.30 | 4.055 | 54.51 | 4.029 | 53.19 |
| | 7.5% | 4.041 | 53.99 | 4.221 | 56.74 | 4.392 | 57.15 |
| | 10.0% | | | 4.121 | 55.40 | 4.149 | 54.77 |

# HEART RATE FOR HOCKEY SUBJECTS

| | | | | | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Subject | Gr. | Trial | Rest | Exercise | 1 | 2 | 3 | 4 | 5 |
| I.B. | 0% | $T_1$ | 96 | 180 | 150 | 118 | 107 | 107 | 105 |
| | | $T_2$ | 73 | 173 | 122 | 110 | 90 | 94 | 90 |
| | | $T_3$ | 71 | 166 | --- | --- | 82 | 76 | 77 |
| T.B. | 0% | $T_1$ | 125 | 141 | 136 | 118 | 113 | 105 | 105 |
| | | $T_2$ | 89 | 161 | 83 | 84 | 91 | 91 | 82 |
| | | $T_3$ | 72 | 170 | 89 | 96 | 95 | 88 | 79 |
| J.F. | 0% | $T_1$ | 79 | 180 | 113 | 98 | 103 | 96 | 103 |
| | | $T_2$ | 64 | 161 | 73 | 76 | 82 | 75 | 68 |
| | | $T_3$ | 61 | 155 | 76 | 61 | 80 | 66 | 76 |
| H.G. | 0% | $T_1$ | 83 | 173 | 105 | 103 | 96 | 90 | 96 |
| | | $T_2$ | 83 | 161 | 110 | 96 | 96 | 82 | 83 |
| | | $T_3$ | 61 | 161 | 96 | 81 | 89 | 79 | 83 |
| R.H. | 0% | $T_1$ | 88 | 166 | 109 | 100 | 92 | 92 | 90 |
| | | $T_2$ | 50 | 155 | 70 | 65 | 92 | 82 | 74 |
| | | $T_3$ | 56 | 180 | 68 | 70 | 75 | 52 | 57 |
| R.J. | 0% | $T_1$ | 96 | 167 | 125 | 115 | 118 | 96 | 105 |
| | | $T_2$ | 74 | 173 | 118 | 94 | 107 | 96 | 94 |
| | | $T_3$ | 81 | 173 | 120 | 99 | 96 | 88 | 99 |
| D.M. | 0% | $T_1$ | 66 | 173 | 85 | 78 | 83 | 74 | 78 |
| | | $T_2$ | 90 | 167 | 110 | 92 | 88 | 92 | 88 |
| | | $T_3$ | 66 | 155 | --- | 81 | 88 | 83 | 74 |
| D.R. | 0% | $T_1$ | 98 | 150 | 145 | 132 | 129 | 122 | 103 |
| | | $T_2$ | 83 | 155 | --- | 96 | 96 | 92 | 94 |
| | | $T_3$ | 89 | 167 | 110 | 106 | 103 | 94 | 87 |
| E.W. | 0% | $T_1$ | 109 | 144 | 130 | 124 | 112 | 109 | 105 |
| | | $T_2$ | 100 | 160 | --- | --- | --- | 94 | 92 |
| | | $T_3$ | 50 | 173 | 90 | 83 | 98 | 75 | 64 |
| R.W. | 0% | $T_1$ | 69 | 204 | 107 | 82 | 87 | 78 | 85 |
| | | $T_2$ | 88 | 161 | 90 | 90 | 88 | 87 | 88 |
| | | $T_3$ | 79 | 173 | 87 | 82 | 85 | 73 | 80 |
| I.B. | 2.5% | $T_1$ | 110 | 195 | 155 | 132 | 118 | 115 | 110 |
| | | $T_2$ | 78 | 180 | 125 | 113 | 98 | 94 | 92 |
| | | $T_3$ | 72 | 173 | 127 | 100 | 94 | 100 | 92 |

| Sub-ject | Gr. | Trial | Rest | Exercise | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| T.B. | 2.5% | $T_1$ | 107 | 145 | 150 | 122 | 113 | 107 | 125 |
| | | $T_2$ | 97 | 173 | 84 | 99 | 99 | 97 | 100 |
| | | $T_3$ | 78 | 166 | 112 | 88 | 96 | 91 | 83 |
| J.F. | 2.5% | $T_1$ | 96 | 187 | 136 | 113 | 105 | 100 | 103 |
| | | $T_2$ | 73 | 167 | 103 | 74 | 94 | 90 | 98 |
| | | $T_3$ | 74 | 183 | 76 | 68 | 80 | 75 | 79 |
| H.G. | 2.5% | $T_1$ | 96 | 187 | 127 | 109 | 96 | 96 | 94 |
| | | $T_2$ | 87 | 173 | --- | --- | 96 | 90 | 92 |
| | | $T_3$ | 87 | 167 | 105 | 83 | 94 | 84 | 89 |
| R.H. | 2.5% | $T_1$ | 87 | 180 | 124 | 100 | 90 | 87 | 77 |
| | | $T_2$ | 71 | 173 | 115 | 71 | 103 | 92 | 87 |
| | | $T_3$ | 64 | 173 | 98 | 98 | 90 | 83 | 80 |
| R.J. | 2.5% | $T_1$ | 115 | 180 | 129 | 122 | 113 | 103 | 105 |
| | | $T_2$ | 103 | 180 | 132 | 108 | 105 | 103 | 98 |
| | | $T_3$ | 99 | 176 | 136 | 105 | 115 | 100 | 97 |
| D.M. | 2.5% | $T_1$ | 74 | 180 | 98 | 90 | 83 | 83 | 88 |
| | | $T_2$ | 74 | 173 | 105 | 94 | 100 | 94 | 90 |
| | | $T_3$ | 61 | 176 | 69 | 94 | 88 | 88 | 78 |
| D.R. | 2.5% | $T_1$ | 118 | 187 | 167 | 132 | 136 | 118 | 118 |
| | | $T_2$ | 90 | 167 | 125 | 98 | 103 | 90 | 90 |
| | | $T_3$ | 96 | 177 | 130 | 123 | 113 | 108 | 99 |
| E.W. | 2.5% | $T_1$ | 105 | 196 | 135 | 124 | 112 | 109 | 102 |
| | | $T_2$ | 110 | 183 | 100 | 104 | 105 | 97 | 104 |
| | | $T_3$ | 71 | 187 | 107 | 92 | 90 | 103 | 100 |
| R.W. | 2.5% | $T_1$ | 90 | 195 | 129 | 107 | 98 | 87 | 87 |
| | | $T_2$ | 94 | 173 | --- | --- | --- | 94 | 87 |
| | | $T_3$ | 82 | 187 | 100 | 82 | 90 | 87 | 87 |
| I.B. | 5.0% | $T_1$ | 115 | 204 | 173 | 161 | 136 | 132 | 136 |
| | | $T_2$ | 100 | 187 | 122 | 113 | 105 | 103 | 100 |
| | | $T_3$ | 90 | 180 | 149 | 114 | 105 | 103 | 103 |
| T.B. | 5.0% | $T_1$ | 113 | 187 | 155 | 113 | 110 | 113 | 110 |
| | | $T_2$ | 91 | 187 | --- | --- | 103 | 103 | --- |
| | | $T_3$ | 94 | 177 | 116 | 100 | 102 | 89 | 88 |
| J.F. | 5.0% | $T_1$ | 107 | 195 | 129 | 113 | 113 | 113 | 110 |
| | | $T_2$ | 96 | 180 | 118 | 103 | 98 | 92 | 96 |
| | | $T_3$ | 85 | 180 | 110 | 88 | 88 | 88 | 87 |

| Subject | Gr. | Trial | Rest | Exercise | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| H.G. | 5.0% | $T_1$ | 109 | 196 | 144 | 120 | 114 | 103 | 109 |
| | | $T_2$ | 100 | 180 | 141 | 107 | 110 | 98 | 105 |
| | | $T_3$ | 90 | 184 | 129 | 101 | 101 | 93 | 91 |
| R.H. | 5.0% | $T_1$ | 82 | 180 | 135 | 124 | 100 | 98 | 98 |
| | | $T_2$ | 90 | 187 | 68 | 103 | 105 | 94 | 88 |
| | | $T_3$ | 78 | 180 | 103 | 94 | 96 | 88 | 79 |
| R.J. | 5.0% | $T_1$ | 105 | 195 | 155 | 125 | 113 | 113 | 118 |
| | | $T_2$ | 114 | 187 | 145 | 125 | 115 | 112 | 115 |
| | | $T_3$ | 104 | 187 | 153 | 125 | 117 | 105 | --- |
| D.M. | 5.0% | $T_1$ | 83 | 187 | 113 | 100 | 90 | 82 | 88 |
| | | $T_2$ | 80 | 180 | 118 | 105 | 103 | 94 | 94 |
| | | $T_3$ | 66 | 180 | 84 | 75 | 97 | 88 | 87 |
| D.R. | 5.0% | $T_1$ | 145 | 195 | 164 | 141 | 136 | 122 | 120 |
| | | $T_2$ | 98 | 161 | 136 | 107 | 103 | 100 | 98 |
| | | $T_3$ | 100 | 180 | 143 | 120 | 122 | 108 | 117 |
| E.W. | 5.0% | $T_1$ | 120 | 196 | 149 | 124 | 124 | 114 | 120 |
| | | $T_2$ | 101 | 199 | 88 | 93 | 107 | 99 | 104 |
| | | $T_3$ | 85 | 195 | 107 | 103 | 103 | 98 | 98 |
| R.W. | 5.0% | $T_1$ | 98 | 195 | 155 | 145 | 110 | 105 | 105 |
| | | $T_2$ | 94 | 180 | 118 | 100 | 96 | 90 | 96 |
| | | $T_3$ | 85 | 180 | --- | 115 | 96 | 92 | 87 |
| I.B. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | | | | | | | |
| | | $T_3$ | 103 | 187 | 155 | 130 | 124 | 120 | 117 |
| T.B. | 7.5% | $T_1$ | 125 | 196 | 150 | --- | 122 | 118 | 118 |
| | | $T_2$ | 98 | 187 | --- | --- | --- | --- | --- |
| | | $T_3$ | 94 | 180 | 140 | 117 | 107 | 100 | 110 |
| J.F. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 100 | 180 | 141 | 110 | 105 | 99 | 110 |
| | | $T_3$ | 78 | 180 | 132 | 107 | 113 | 98 | 103 |
| H.G. | 7.5% | $T_1$ | 114 | 196 | 166 | 140 | 124 | 117 | 124 |
| | | $T_2$ | 105 | 187 | 161 | 125 | 115 | 107 | 105 |
| | | $T_3$ | 97 | 183 | 145 | 114 | 110 | 108 | 104 |
| R.H. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 88 | 180 | 136 | 100 | 107 | 96 | 90 |
| | | $T_3$ | 88 | 187 | 122 | 122 | 107 | 92 | 90 |

| Subject | Gr. | Trial | Rest | Exercise | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| R.J. | 7.5% | $T_1$ | 113 | 195 | 167 | 141 | 129 | 122 | 115 |
| | | $T_2$ | 123 | 195 | 164 | 134 | 118 | 115 | 112 |
| | | $T_3$ | 113 | 190 | 165 | 134 | 122 | 115 | 113 |
| D.M. | 7.5% | $T_1$ | 94 | 195 | 145 | 115 | 105 | 105 | 113 |
| | | $T_2$ | 88 | 187 | 122 | 100 | 103 | 98 | 98 |
| | | $T_3$ | 78 | 187 | 122 | 94 | 102 | 82 | 89 |
| E.W. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 102 | 199 | 145 | 125 | 114 | 108 | 120 |
| | | $T_3$ | 107 | 204 | 141 | 122 | 107 | 100 | 105 |
| R.W. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 105 | 187 | 141 | 122 | 105 | 96 | 100 |
| | | $T_3$ | --- | 195 | 145 | 110 | 100 | 90 | 96 |
| T.B. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | --- | 187 | 161 | 141 | 125 | 115 | 118 |
| | | $T_3$ | 113 | 180 | 144 | 118 | 113 | 110 | 104 |
| H.G. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | 115 | 187 | 155 | 122 | 118 | 107 | 105 |
| | | $T_3$ | | | | | | | |
| R.J. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | | | | | | | |
| | | $T_3$ | 136 | 180 | 161 | 129 | 115 | 107 | 107 |
| D.M. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | 107 | 195 | 141 | 118 | 110 | 103 | 98 |
| | | $T_3$ | 91 | 195 | 147 | --- | 114 | 106 | 109 |
| E.W. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | 123 | 199 | 177 | 145 | 123 | 123 | 131 |
| | | $T_3$ | 110 | 204 | 167 | 129 | 115 | 110 | 107 |
| D.M. | 12.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 100 | 187 | 150 | 125 | 118 | 107 | 105 |
| | | $T_3$ | 107 | 187 | 158 | 136 | 122 | 118 | --- |

# HEART RATE FOR CONTROL SUBJECTS

| | | | | | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Subject | Gr. | Trial | Rest | Exercise | 1 | 2 | 3 | 4 | 5 |
| B.B. | 0% | $T_1$ | 118 | 195 | 173 | 141 | 136 | 129 | 132 |
| | | $T_2$ | 122 | 187 | 195 | 141 | 150 | 129 | 141 |
| | | $T_3$ | 113 | 195 | 180 | 132 | 141 | 132 | 129 |
| G.C. | 0% | $T_1$ | 115 | 187 | 150 | 129 | 129 | 118 | 115 |
| | | $T_2$ | 100 | 195 | 150 | 122 | 122 | 113 | 105 |
| | | $T_3$ | 103 | 195 | 136 | 122 | 115 | 110 | 112 |
| W.C. | 0% | $T_1$ | 96 | 187 | 136 | 122 | 115 | 103 | 113 |
| | | $T_2$ | 90 | 180 | 125 | 110 | 115 | 87 | 94 |
| | | $T_3$ | 87 | 173 | 125 | 107 | 103 | 94 | 100 |
| L.F. | 0% | $T_1$ | 100 | 195 | 105 | 110 | 115 | 103 | 110 |
| | | $T_2$ | 103 | 195 | 145 | 118 | 118 | 107 | 105 |
| | | $T_3$ | 108 | 191 | 130 | 125 | 118 | 106 | 111 |
| J.G. | 0% | $T_1$ | 96 | 173 | 130 | 83 | 114 | 100 | 109 |
| | | $T_2$ | 85 | 173 | 125 | 98 | 100 | 98 | 78 |
| | | $T_3$ | 90 | 173 | 129 | 114 | 110 | 104 | 90 |
| B.K. | 0% | $T_1$ | 100 | 173 | 141 | 118 | 113 | 107 | 110 |
| | | $T_2$ | 115 | 180 | 145 | 125 | 122 | 115 | 115 |
| | | $T_3$ | 98 | 165 | 136 | 112 | 107 | 105 | 101 |
| W.M. | 0% | $T_1$ | 107 | 195 | 150 | 125 | 125 | 115 | 115 |
| | | $T_2$ | 113 | 187 | --- | 115 | --- | 112 | 96 |
| | | $T_3$ | 88 | 187 | 129 | 110 | 107 | 107 | 103 |
| J.M. | 0% | $T_1$ | 122 | 180 | 141 | 125 | 125 | 113 | 113 |
| | | $T_2$ | 103 | 173 | 141 | 122 | 118 | 110 | 118 |
| | | $T_3$ | 100 | 166 | 127 | 114 | 114 | 100 | 105 |
| R.N. | 0% | $T_1$ | 96 | 173 | 141 | 112 | 108 | 104 | 105 |
| | | $T_2$ | 92 | 161 | 110 | 80 | 88 | 90 | 96 |
| | | $T_3$ | 61 | 167 | 90 | 92 | 85 | 79 | 79 |
| J.P. | 0% | $T_1$ | 132 | 187 | 145 | 132 | 122 | 118 | 122 |
| | | $T_2$ | 129 | 173 | 145 | 122 | 122 | 113 | 122 |
| | | $T_3$ | 105 | 167 | 132 | 118 | 114 | 104 | 106 |
| B.B. | 2.5% | $T_1$ | 136 | 195 | 180 | 155 | 145 | 141 | 145 |
| | | $T_2$ | 136 | 195 | 180 | 155 | --- | 141 | 141 |
| | | $T_3$ | 136 | 204 | 180 | 145 | 136 | 125 | 141 |

| | | | | | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Subject | Gr. | Trial | Rest | Exercise | 1 | 2 | 3 | 4 | 5 |
| G.C. | 2.5% | $T_1$ | 122 | 195 | 167 | 136 | 129 | 118 | 113 |
| | | $T_2$ | 113 | 195 | 150 | 125 | 122 | 122 | 115 |
| | | $T_3$ | 115 | 198 | 161 | 129 | 124 | 115 | 110 |
| W.C. | 2.5% | $T_1$ | 103 | 187 | 150 | 125 | 118 | 110 | 110 |
| | | $T_2$ | 98 | 187 | 150 | --- | 107 | 103 | 103 |
| | | $T_3$ | 96 | 180 | 141 | 125 | 115 | 105 | 107 |
| L.F. | 2.5% | $T_1$ | 100 | 204 | 161 | 141 | 125 | 125 | 115 |
| | | $T_2$ | 110 | 204 | 155 | 125 | 122 | 127 | 118 |
| | | $T_3$ | 111 | 195 | 145 | 129 | 115 | 114 | 107 |
| J.G. | 2.5% | $T_1$ | 96 | 187 | 155 | 120 | 120 | 117 | 112 |
| | | $T_2$ | 96 | 180 | 129 | 110 | 105 | 94 | 92 |
| | | $T_3$ | 100 | 180 | 141 | 111 | 113 | 103 | 98 |
| B.K. | 2.5% | $T_1$ | 113 | 187 | 141 | 129 | 118 | 113 | 110 |
| | | $T_2$ | 113 | 187 | 167 | 136 | 129 | 122 | 125 |
| | | $T_3$ | 105 | 173 | 145 | 123 | 114 | 105 | 107 |
| W.M. | 2.5% | $T_1$ | 115 | 195 | 150 | 125 | 122 | 118 | 122 |
| | | $T_2$ | 94 | 195 | 141 | 118 | 107 | 110 | --- |
| | | $T_3$ | 100 | 187 | 145 | 118 | 115 | 115 | 115 |
| J.M. | 2.5% | $T_1$ | 145 | 195 | 155 | 136 | 129 | 118 | 116 |
| | | $T_2$ | 129 | 195 | 141 | 125 | 122 | 115 | 118 |
| | | $T_3$ | 103 | 176 | 127 | 124 | 117 | 105 | 109 |
| R.N. | 2.5% | $T_1$ | 107 | 187 | 155 | 122 | 115 | 110 | 107 |
| | | $T_2$ | 88 | 173 | 115 | 96 | 96 | 92 | 96 |
| | | $T_3$ | 87 | 173 | 122 | 105 | 96 | 83 | 88 |
| J.P. | 2.5% | $T_1$ | 122 | 187 | 141 | 122 | 129 | 122 | 132 |
| | | $T_2$ | 122 | 180 | 140 | 120 | 126 | 120 | 116 |
| | | $T_3$ | 104 | 177 | 141 | 116 | 115 | 108 | 114 |
| B.B. | 5.0% | $T_1$ | | | | | | | |
| | | $T_2$ | 150 | 214 | --- | 141 | 161 | 129 | 132 |
| | | $T_3$ | 132 | 195 | 173 | 141 | 136 | 132 | 129 |
| G.C. | 5.0% | $T_1$ | 129 | 195 | 173 | 141 | 129 | 118 | 122 |
| | | $T_2$ | 125 | 205 | 161 | 136 | 125 | 118 | 118 |
| | | $T_3$ | 113 | 195 | 167 | 136 | 129 | 118 | 118 |
| W.C. | 5.0% | $T_1$ | 113 | 195 | 161 | 136 | 125 | 118 | 122 |
| | | $T_2$ | 103 | 187 | 155 | 132 | 122 | 113 | 115 |
| | | $T_3$ | 105 | 187 | 155 | 136 | 125 | 115 | 113 |

| Sub-ject | Gr. | Trial | Rest | Exercise | Recovery | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 |
| L.F. | 5.0% | $T_1$ | 122 | 214 | 167 | 150 | 141 | 125 | 118 |
| | | $T_2$ | 122 | 214 | 173 | 145 | 132 | 125 | --- |
| | | $T_3$ | 107 | 200 | --- | 141 | 132 | 120 | 122 |
| J.G. | 5.0% | $T_1$ | 124 | 187 | 149 | 127 | 130 | 120 | 109 |
| | | $T_2$ | 92 | 180 | 150 | 115 | 113 | 107 | 107 |
| | | $T_3$ | 98 | 180 | 145 | 118 | 112 | 107 | 105 |
| B.K. | 5.0% | $T_1$ | 118 | 180 | 150 | 129 | 115 | 110 | 113 |
| | | $T_2$ | 136 | 187 | 155 | 141 | 125 | 122 | --- |
| | | $T_3$ | 100 | 173 | 145 | 123 | 108 | 108 | 102 |
| W.M. | 5.0% | $T_1$ | 115 | 204 | 160 | 114 | 122 | 116 | 114 |
| | | $T_2$ | 122 | 204 | 155 | 113 | 125 | 115 | 115 |
| | | $T_3$ | 113 | 195 | 150 | 125 | 122 | 118 | 122 |
| J.M. | 5.0% | $T_1$ | 136 | 195 | 143 | 129 | 122 | 115 | 113 |
| | | $T_2$ | 129 | 195 | 155 | 132 | 129 | 129 | 125 |
| | | $T_3$ | 112 | 180 | 142 | 117 | 117 | 109 | 117 |
| R.N. | 5.0% | $T_1$ | 118 | 195 | 161 | 136 | 129 | 132 | 132 |
| | | $T_2$ | 92 | 180 | 136 | 122 | 105 | 96 | 90 |
| | | $T_3$ | 98 | --- | --- | --- | --- | --- | --- |
| J.P. | 5.0% | $T_1$ | 129 | 195 | 167 | 136 | 132 | 118 | 125 |
| | | $T_2$ | --- | --- | 160 | 132 | 120 | 124 | 128 |
| | | $T_3$ | 113 | 180 | 145 | 130 | 120 | 115 | 118 |
| G.C. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | | | | | | | |
| | | $T_3$ | 132 | 195 | 170 | 145 | 136 | 132 | 123 |
| W.C. | 7.5% | $T_1$ | 122 | 187 | 161 | 145 | 132 | 125 | 122 |
| | | $T_2$ | 110 | 195 | 161 | --- | 125 | 118 | 118 |
| | | $T_3$ | 118 | 187 | 155 | 136 | 125 | 118 | 122 |
| L.F. | 7.5% | $T_1$ | 128 | 206 | 152 | 140 | 120 | 124 | 120 |
| | | $T_2$ | 120 | 214 | 154 | 140 | 124 | 123 | 120 |
| | | $T_3$ | 123 | 200 | 153 | 138 | 120 | 118 | 111 |
| J.G. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 107 | 173 | 136 | 113 | 107 | 100 | 96 |
| | | $T_3$ | | | | | | | |
| W.M. | 7.5% | $T_1$ | | | | | | | |
| | | $T_2$ | 122 | 204 | 141 | 129 | --- | 120 | --- |
| | | $T_3$ | 129 | 187 | 155 | 132 | 129 | 125 | 122 |

| Subject | Gr. | Trial | Rest | Exercise | Recovery 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|
| R.N. | 7.5% | $T_1$ | 136 | 187 | 167 | 150 | 136 | 136 | 132 |
| | | $T_2$ | 107 | 180 | 155 | 126 | 115 | 113 | 113 |
| | | $T_3$ | --- | 187 | 136 | 116 | 108 | 104 | 104 |
| J.P. | 7.5% | $T_1$ | 141 | 195 | 173 | 155 | 141 | 129 | 136 |
| | | $T_2$ | 120 | 195 | 176 | 136 | 124 | 120 | 120 |
| | | $T_3$ | 118 | 183 | 150 | 125 | 129 | 115 | 125 |
| R.N. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | | | | | | | |
| | | $T_3$ | 115 | 180 | 150 | 136 | 118 | 113 | 118 |
| J.P. | 10.0% | $T_1$ | | | | | | | |
| | | $T_2$ | 140 | --- | 164 | 148 | 138 | 132 | 126 |
| | | $T_3$ | 123 | 187 | 158 | 130 | 122 | 118 | 115 |

## RECOVERY OXYGEN CONSUMPTION FOR THE HOCKEY GROUP

| | | TEST I | | TEST II | | TEST III | |
|---|---|---|---|---|---|---|---|
| Subject | Gr. | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) |
| I.B. | 0% | .695 | 8.286 | .555 | 6.751 | .442 | 5.512 |
| | 2.5% | .906 | 10.801 | .721 | 8.781 | .675 | 8.451 |
| | 5.0% | 1.292 | 15.440 | .833 | 10.162 | .800 | 10.071 |
| | 7.5% | | | | | .858 | 10.760 |
| T.B. | 0% | .804 | 3.982 | .573 | 7.340 | .526 | 6.772 |
| | 2.5% | .655 | 8.200 | .608 | 7.820 | .574 | 7.391 |
| | 5.0% | .738 | 9.291 | .675 | 8.650 | .805 | 10.390 |
| | 7.5% | .792 | 9.933 | .830 | 10.652 | .909 | 11.741 |
| | 10.0% | | | .864 | 11.081 | .827 | 10.681 |
| J.F. | .0% | .476 | 7.182 | .423 | 6.376 | .553 | 8.351 |
| | 2.5% | .353 | 5.462 | .476 | 7.182 | .545 | 8.232 |
| | 5.0% | ---- | ----- | ---- | ----- | .658 | 9.934 |
| | 7.5% | ---- | ----- | .730 | 9.050 | .694 | 10.494 |
| H.G. | .0% | .659 | 7.892 | .571 | 7.064 | .694 | 8.551 |
| | 2.5% | .713 | 8.554 | .996 | 12.356 | ---- | ----- |
| | 5.0% | .800 | 9.596 | .737 | 9.132 | .723 | 8.961 |
| | 7.5% | .891 | 10.681 | .841 | 10.450 | .956 | 11.800 |
| | 10.0% | ---- | ------ | .852 | 10.561 | ---- | ------ |
| R.H. | .0% | 1.041 | 14.490 | .837 | 11.772 | .608 | 8.321 |
| | 2.5% | .725 | 10.060 | .799 | 11.233 | .695 | 9.522 |
| | 5.0% | .976 | 13.572 | .848 | 11.934 | .829 | 11.371 |
| | 7.5% | ---- | ------ | .787 | 11.070 | .884 | 12.131 |
| R.J. | .0% | .654 | 8.332 | .577 | 7.512 | .573 | 7.432 |
| | 2.5% | .759 | 9.670 | .746 | 9.740 | .632 | 8.200 |
| | 5.0% | .881 | 11.231 | .868 | 11.354 | .783 | 10.151 |
| | 7.5% | .975 | 12.446 | .856 | 11.181 | .811 | 10.531 |
| | 10.0% | ---- | ------ | ---- | ------ | .755 | 9.801 |
| D.M. | .0% | .201 | 2.570 | .540 | 7.032 | .559 | 7.460 |
| | 2.5% | .286 | 3.674 | .545 | 7.101 | .559 | 7.460 |
| | 5.0% | .480 | 6.203 | .645 | 8.421 | .827 | 11.064 |
| | 7.5% | .333 | 4.291 | .813 | 10.621 | .991 | 13.272 |
| | 10.0% | ---- | ----- | ---- | ------ | 1.55 | 20.833 |
| | 12.5% | ---- | ----- | 1.08 | 14.05 | .614 | 8.241 |
| E.W. | .0% | .591 | 8.131 | .713 | 9.906 | .500 | 7.052 |
| | 2.5% | .709 | 9.780 | .633 | 8.787 | .595 | 8.400 |
| | 5.0% | .826 | 11.405 | .791 | 10.981 | .686 | 9.690 |
| | 7.5% | ---- | ------ | .914 | 12.700 | .632 | 8.943 |
| | 10.0% | ---- | ------ | .982 | 13.642 | .804 | 11.392 |

|  |  | TEST I |  | TEST II |  | TEST III |  |
|---|---|---|---|---|---|---|---|
| Subject | Gr. | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) |
| R.W. | 0% | .605 | 6.981 | .594 | 6.992 | .559 | 6.211 |
|  | 2.5% | .699 | 8.070 | .681 | 8.034 | .668 | 8.042 |
|  | 5.0% | .913 | 10.540 | .808 | 9.535 | .774 | 9.873 |
|  | 7.5% | ---- | ------ | 1.02 | 12.051 | .920 | 11.081 |
| D.R. | .0% | .829 | 10.461 | .725 | 9.135 | .774 | 9.442 |
|  | 2.5% | .875 | 11.040 | .850 | 10.721 | .914 | 11.144 |
|  | 5.0% | .900 | 11.345 | 1.02 | 12.902 | .953 | 11.621 |

## RECOVERY OXYGEN CONSUMPTION FOR THE CONTROL GROUP

| Subject | Gr. | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) | (L/min) | (ml/kg/min) |
|---|---|---|---|---|---|---|---|
| B.B. | 0% | .837 | 9.661 | .763 | 8.810 | ---- | ---- |
| | 2.5% | 1.110 | 13.064 | .859 | 10.130 | ---- | ---- |
| | 5.0% | ----- | ------ | .567 | 6.684 | .772 | 9.112 |
| G.C. | .0% | .996 | 15.401 | .605 | 9.331 | .538 | 8.296 |
| | 2.5% | .781 | 12.077 | .211 | 3.210 | .503 | 7.704 |
| | 5.0% | .795 | 12.291 | .731 | 11.280 | .695 | 10.661 |
| | 7.5% | ---- | ------ | ---- | ------ | .631 | 9.720 |
| W.C. | .0% | .462 | 5.941 | .492 | 6.332 | .357 | 4.581 |
| | 2.5% | .618 | 8.063 | .661 | 8.624 | .340 | 4.400 |
| | 5.0% | .664 | 8.563 | .763 | 9.960 | .784 | 10.180 |
| | 7.5% | .645 | 8.321 | .848 | 11.081 | .740 | 9.593 |
| L.F. | .0% | .719 | 10.501 | .693 | 10.130 | .500 | 7.298 |
| | 2.5% | 1.190 | 10.471 | .846 | 12.545 | .601 | 8.892 |
| | 5.0% | 1.041 | 15.272 | .942 | 13.981 | .807 | 12.133 |
| | 7.5% | .724 | 10.583 | .699 | 10.366 | .647 | 9.703 |
| J.G. | .0% | 1.02 | 12.491 | .665 | 8.094 | .573 | 6.972 |
| | 2.5% | .280 | 15.950 | .758 | 9.453 | .883 | 11.012 |
| | 5.0% | .956 | 11.650 | .949 | 11.842 | .829 | 9.892 |
| | 7.5% | ---- | ------ | .733 | 9.131 | ---- | ------ |
| B.K. | .0% | .779 | 8.991 | .709 | 8.183 | 1.164 | 13.401 |
| | 2.5% | .733 | 8.370 | 1.780 | 10.752 | .849 | 9.710 |
| | 5.0% | .719 | 8.294 | .774 | 8.851 | .743 | 8.440 |
| W.M. | .0% | .725 | 8.586 | .629 | 7.444 | .611 | 7.232 |
| | 2.5% | .790 | 9.471 | .741 | 8.883 | .751 | 8.994 |
| | 5.0% | --- | ----- | .904 | 10.843 | .715 | 8.386 |
| | 7.5% | --- | ----- | .747 | 8.961 | .685 | 8.030 |
| J.M. | 0% | .845 | 10.971 | .739 | 9.591 | .672 | 8.713 |
| | 2.5% | .923 | 11.651 | .823 | 10.384 | .716 | 9.022 |
| | 5.0% | .821 | 10.662 | 1.050 | 13.233 | .404 | 5.133 |
| R.N. | .0% | .628 | 8.711 | 1.020 | 14.092 | .658 | 9.12 |
| | 2.5% | .703 | 10.073 | .615 | 8.806 | .740 | 10.602 |
| | 5.0% | .920 | 12.772 | .733 | 10.681 | .911 | 12.663 |
| | 7.5% | .812 | 11.274 | ---- | ------ | .712 | 9.871 |
| J.P. | 0% | ---- | ------ | .994 | 13.226 | .502 | 6.651 |
| | 2.5% | .854 | 11.431 | .752 | 10.050 | .658 | 8.784 |
| | 5.0% | 1.352 | 18.022 | .986 | 13.191 | .713 | 9.351 |
| | 7.5% | 1.046 | 13.921 | 1.051 | 14.083 | .945 | 12.423 |
| | 10.0% | ---- | ------ | .973 | 13.031 | .888 | 11.676 |

# APPENDIX D

# CORRECTION FACTORS

## CORRECTIONS FOR AMERICAN METER CO. GAS METER #802

This meter was tested for its volume determinations using as standards the large Tissot tank in the Faculty of Physical Education Laboratory and a smaller Tissot in the Cardio-pulmonary Laboratory at the University Hospital. It was found to be recording volume readings in excess of actual volumes pumped, as indicated by the Tissot tanks. A second American Meter Co. gas meter, in use in the University Hospital, was found to give extremely accurate readings when compared to the same Tissot tanks.

The data collected was analyzed and a regression equation calculated. This equation was found to be,

$$Y = .22770 + .943099\ X$$

where $Y$ = corrected volume

and $X$ = volume as read on the American Meter Co. Gas Meter #802.

This regression equation was then used to calculate a complete set of correction tables. These tables also incorporate a factor for loss of volume during oxygen and carbon dioxide analysis, with the factor being considered as 300 c.c.

## CORRECTIONS FOR THE BECKMAN E-2 OXYGEN ANALYZER.

The accuracy of this instrument was tested against two micro-Scholander instruments operated by laboratory technicians in the Cardio-pulmonary Laboratory of the University of Alberta Hospital and the laboratory of the Department of Physiology at the University of Alberta.

The values obtained with the two Scholanders were averaged and a regression equation based on the Beckman reading and the Scholander values was calculated. This equation was found to be,

$$Y' = .893X \quad 2.22$$

where Y' = the corrected percentage of oxygen

and X = the percentage of oxygen as read on the Beckman E-2 analyzer.

The discrepancy was found to be due to impure nitrogen which was used as a calibration gas.

Based on the above regression equation, a second regression line was calculated which permitted direct correction of oxygen consumption values. This equation was found to be,

$$Y' = .871X \quad .004$$

where Y' = corrected oxygen consumption in liters per minute

and X = oxygen consumption value obtained on the basis of the uncorrected percentage of oxygen as obtained on the Beckman analyzer.

After testing with the same Micro-Scholanders, the

Godart Capnograph infra-red carbon dioxide analyzer was found to give accurate readings.

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